SYSTEM FOR REPORTING MALFUNCTIONING BIOMEDICAL DEVICES IN ACCRA, GHANA

A Major Qualifying Project Report:

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Table of Contents

Authorship Page

Section	Author
Acknowledgements	Both
Abstract	Elisabeth
Executive Summary	Elisabeth
Chapter 1: Introduction	Ana
Chapter 2: Literature Review	Ana
History of Ghanaian Healthcare	Ana
Ghana Healthcare Sector	Ana
The Greater Accra Regional Hospital	Ana
Medical Devices and Definitions	Elisabeth
Prior Art	Ana
Current System	Ana
CEU App System	Elisabeth
Lightwave Health Information Management System	Ana
Chapter 3: Project Approach	Ana
Project Strategy	Elisabeth
Client Needs	Elisabeth
Engineering Department	Ana
Nurses	Elisabeth
Management	Elisabeth
Technical Design Requirements	Ana
Objectives	Ana
Constraints	Elisabeth
Functions	Elisabeth
Specifications	Elisabeth
Pairwise Comparison	Elisabeth
Standards	Elisabeth
Chapter 4: Design Process	Ana
Design Option 1: Basic Website Form	Ana
Design Option 2: LHIMS Integration	Elisabeth
Design Option 3: Tagging System	Elisabeth
Design Option 4: Web Application	Ana
Concept Comparison	Ana
Pugh Matrix	Elisabeth
Competitive Analysis	Elisabeth
Final Design Selection	Elisabeth
Chapter 5: Design Verification	Ana
Engineer Subsystem	Ana
Nurse Subsystem	Ana
Management Subsystem	Ana

Future Verification	Ana
Chapter 6: Final Design Validation	Ana
Validation Method Analysis	Elisabeth
Proposal Verification	Ana
Design Impact	Elisabeth
Economics	Ana
Environmental Impact and Sustainability	Ana
Societal Influence	Ana
Political Ramifications	Ana
Ethical Concerns and Health and Safety Issues	Ana
Chapter 7: Discussion	Ana
Chapter 8: Conclusions and Recommendations	Ana
Appendix	Both

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This image is from our first meeting at the Greater Accra Regional Hospital. From left to right: Dr. Phillip A. Bannor, Ana Grandgeorge, Dr. Emmanuel K. Srofenyoh, Elisabeth Lynn, and Professor Robert Krueger. We are extremely grateful for our time at GARH and hope that in the future there are more opportunities for WPI students to work here.

This image is from our last day at the Greater Accra Regional Hospital with those completing their year of service at the Clinical Engineering Unit. We are grateful for their friendship, mentorship, and guidance, and wish them all the best in their future endeavors.

Abstract

This MQP project investigates the medical device reporting system at the Greater Accra Regional Hospital. Through research, interviews, and observations completed through shadowing the engineering department, the necessary information was acquired to create a new system tending to the clients' needs. It was found that the main issues with the system are poor communication between the head nurses and the clinical engineering department, and inefficiency, which takes time away from the clinical engineering department's main focus and responsibility of repairing equipment. The proposed design is a web application that decreases the time between the device being reported and picked up for repair and allows engineers to update nurses on progress.

Executive Summary

The Greater Accra Regional Hospital (GARH), formerly known as Ridge Regional Hospital, is located in the center of Ghana's capital, Accra. With the majority of Ghana's medical devices consisting of imports, GARH as well as many other hospitals in Ghana rely heavily on clinical engineering units to maintain their medical equipment. The clinical engineering unit at GARH consists of only five permanent workers to maintain the equipment of over 50 units within the hospital.

The Greater Accra Regional Hospital is in need of an efficient system of reporting medical device malfunctions. To address this, an ethnographic approach was used to understand and identify key issues within the system so that a new system could be designed and proposed.

The clinical engineering department was observed for approximately four weeks in order to gain an understanding of the current system at the hospital. Interviews with key stakeholders such as the hospital's CEO, members of IT, and the head of the clinical engineering unit were also conducted. Based on these observations, it was found that the main issues with the current system were related to communication between the head nurses and engineers, and lack of efficiency. No progress updates were given to the nurses on their device concerns between the time the device was picked up and returned. Additionally, the current rounds system and the paperwork involved with it increased the time from the device being reported as broken to the device being picked up by engineers to be fixed.

The methodologies listed above guided the following product specifications:

1. **Proper Communication**: The system should improve communication between the head nurses and the engineering department.

2. **User Friendly**: The system needs to be simple to navigate and easy for all users to learn. Otherwise, no one will have a desire to pick up the new system, causing more complaints than the current system.
3. **Secure**: The system must be secure as it relates to medical data. Only those who need to use the system should have access to it. The data collected on the medical devices and their issues should be safely stored and made available to the engineering department head and hospital management.
4. **Time Efficient**: The system must be efficient and reduce downtime. Decreases in the time between a device being broken and returned to operation in the unit, the time it takes for rounds to occur, and the amount of time that the engineers spend talking on the phone about issues should be seen. This specification allows the engineers to have more time to focus on getting the device functioning as soon as possible.
5. **Accurate:** The system should allow for data on devices and issues to be accurate.
6. **Accessible**: All components of the system must be easy to find. If the system is digital, it should have a quick link and if non-digital, components should be in a central standard location. The system itself should be accessible on computers, phones, and tablets.
7. **Affordable**: The system must be affordable for the hospital. Any costs related to service and maintenance of the system should also be accounted for.

After brainstorming and comparative analysis, the final design for the new system was developed. The final design is a web application of which users can digitally complete requests for broken medical devices and engineers can update nurses on the device progress. The system follows the rules set by Ghana National Health Services.

This document includes a proposal for what the ideal application would look like and how it should be implemented. In order to validate the design, feedback on the proposal was received by key stakeholders and computer science students from WPI. The goal is that in the future, another MQP team will use this proposal to develop and implement this new system into the hospital. The system is designed to be flexible so that if successful, it can be implemented in hospitals across Ghana.

Through immersive observation of the engineering department, a new system was designed that was tailored to the clients' needs and concerns. This approach allowed the client perspective to be at the forefront of the design process so that the those who create the platform in the future have a clear understanding of the need for its proposed features. If the application is implemented, it has the potential to have a positive impact on the people and patients of the Greater Accra Regional Hospital.

Table of Figures

Table of Tables

Chapter 1: Introduction

Ghana is a country located in West Africa, on the coast of the Gulf of Guinea (*Ghana | History, Flag, Map, Population, Language, Currency, & Facts | Britannica*). It shares borders with Cote d'Ivoire to the west, Burkina Faso to the north, and Togo to the east. The Greater Accra Regional Hospital is a tertiary care hospital located in Ghana's capital, Accra. The clinical engineering department at the hospital manages the maintenance and repair of the medical devices within the hospital. There are three engineers and two technicians who work full-time in the clinical engineering department. There are also approximately ten temporary workers assigned to the department each year, completing their year of National Service. The National Service Scheme is a mandate for all those who have completed their tertiary courses to then complete a year of service to develop skills and plan for long-term employment (*Rules*, n.d.). The National Service workers at the Greater Accra Regional Hospital are trained in different types of equipment over the course of their year of service. Because there are only five permanent workers to serve such a large hospital, and because it is time consuming to train the National Service Engineers, time is of the essence in all aspects of their work.

The current system for reporting broken medical devices to the clinical engineering department is time consuming, inefficient, and lacks a consistent method of communication after the devices have been taken for repair. The engineers use a paperwork system and go to each of the 50+ units in the hospital to see if they have any issues with any of the devices. After the devices are taken, the nurses have no way of receiving progress updates on the devices.

The goal of this project is to work with the clinical engineering department to develop a more efficient system. This system should reduce the time it takes for devices to be reported and

open communication between the nurses and the clinical engineers. The system should also be adaptable to any changes in the clients' needs in the future.

For this project, we conducted background research and interviews to better understand the health sector in Ghana and the need for our project. We then shadowed the clinical engineering department to understand their process and collect quantitative and observational data to guide our specifications. Based on the data and the resulting specifications, we developed four design concepts to meet the clients' needs.

This report goes through the background research conducted to gain a better understanding of the different elements that contribute to the overall need. The current system and a competitive system are discussed in prior art. The project strategy is discussed as well as the client needs, and design requirements based on the observational data collected. Four different designs are presented and compared against each other and the prior art. The design is verified by each individual subsystem, and because the design is conceptual, guidelines for future verification are suggested. The verification method is analyzed, and the design's potential impacts are discussed. The accomplishments, process, and limitations are reviewed, and future recommendations are made for another team to continue the work we have begun.

This work is important because it aids in the delivery of efficient and functioning medical devices for the Greater Accra Regional Hospital. Medical devices cover a broad range of care and functioning medical devices are crucial to the health and safety of each patient that enters the hospital. Any way that the system for monitoring devices in the hospital can be improved directly affects the care given to each patient and overall efficacy of the hospital.

Chapter 2: Literature Review

To appreciate the need for our project, it is important to get a broader understanding of the various factors that influence Ghanaian healthcare, the hospital that we are working with, and the prior art.

2.1 History of Ghanaian Healthcare

An understanding of the history of Ghana is important to understand how its current healthcare system came to be. In 1874, the British occupied Ghana and established it as a crown colony. Ghana regained its independence on March 6th, 1957 (*Ghana Summary | Britannica*), however some of the European influence in Ghana can still be seen today, particularly in the distribution of health care infrastructure (Adu-Gyamfi et al.). Prior to the arrival of Europeans, Ghanaian healthcare relied on traditional healers and herbal medicine for treatment of ailments. After the British arrived, they established a colonial health infrastructure (Adu-Gyamfi et al.), through it was primarily intended to serve themselves and not the Ghanaian people (Fatunde and Bhatia). Through the expansion of this infrastructure, the Ghanaian people gradually began to use these health facilities, though many of the healthcare facilities were in areas with large European populations. This distribution of facilities is still visible today (Fatunde and Bhatia).

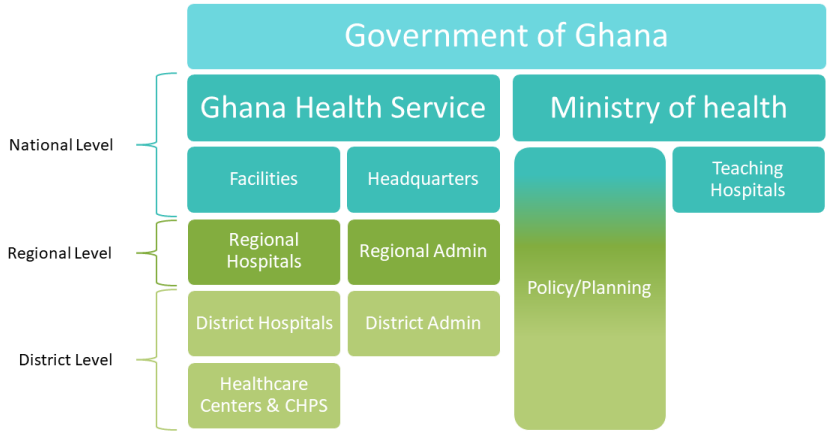
Though numerous local ordinances and laws were passed in attempts to regulate healthcare and sanitation (Adu-Gyamfi et al.), there was no cohesive national health care system during British rule (Fatunde and Bhatia). Following independence in 1957, the Ministry of Health was established to "contribute to socio-economic development and the development of a local health industry by promoting health and vitality through access to quality health" care for Ghanaians ("The Ministry"). The number of facilities for health care increased considerably

during this time. However, as much of the focus was on the creation of facilities and not on the services themselves, the burden of diseases also increased. It was not until the late 1970s that a more concerted effort was made to focus on primary care rather than the creation of large facilities (Fatunde and Bhatia). Though issues like accessibility still prevail in rural areas, government efforts to improve the healthcare in Ghana continue to this day (Boateng-Ade).

2.2 Ghana Healthcare Sector

The Ghana Health Service (GHS) is one of two main governing entities that make up Ghana's health sector. The responsibility of managing and operating public health facilities in Ghana falls on the GHS (Couttolenc, Chapter 1). It was established in 1996 under the Ghana Health Service and Teaching Hospitals Act, in accordance with the Constitution of the Republic of Ghana of 1992 to implement national policies from the Ministry of Health (MOH) (*Profile of GHS – Ghana Health Service*). The MOH is the other main governing entity, and it is responsible for policy making, regulation, and maintaining the three teaching hospitals in Ghana (Couttolenc, Chapter 1). Shown below is a chart of the two entities, organized by national, regional, and district level.

Figure 1: Chart of Ghana's Health Sector



Both entities are organized at the national, regional, and district level (*Organization of GHS – Ghana Health Service*). Additionally, the GHS oversees all four levels of care: Community Health Planning and Services Zones (CHPS), Health Centers/Polyclinics, District Hospitals and Regional Hospitals (*Organization of GHS – Ghana Health Service*).

As part of overseeing the hospitals, the GHS is responsible for the regulation, operation, and maintenance of medical devices, in conjunction with the appropriate regulatory bodies in Ghana. These include the Food and Drug Administration (FDA), Nuclear Regulatory Authority (NRA), and the Ghana Standards Authority (GSA) and this collaboration ensures the safety of the devices (*Medical Equipment Policy and Guidelines*).

2.3 The Greater Accra Regional Hospital

The Greater Accra Regional Hospital (GARH) is a hospital located in the center of Accra. As a regional hospital, it serves the Greater Accra region of Ghana, with an estimated population of 5,455,692 as of 2021 (*Ghana Statistical Services.*). It originally opened in 1928 as a hospital to primarily serve the European population in Ghana at the time, though some of the

infrastructure and equipment dated back to 1911-1923 (*History & Background – Greater Accra Regional Hospital*). Following Ghana's independence in 1957, it was designated as a district hospital. In 1997, its designation was updated to a regional hospital and was renamed Ridge Regional Hospital. Because some of the infrastructure dated as far back as 1911, Ridge Hospital required a significant amount of yearly maintenance. In 2014, construction started on a new facility to expand on the original (Johnson). Completed in 2017 (Davis), this renovation increased capacity from 192 beds to 420 (*History & Background – Greater Accra Regional Hospital*). The new building became the first on the African continent to receive the LEED Silver Certification for Healthcare (Bosch). The new hospital was renamed to its current name, the Greater Accra Regional Hospital. A second phase of expansion is planned for the hospital which would add 200 beds, bringing the total capacity to 620 (*History & Background – Greater Accra Regional Hospital*).

As is, the hospital provides a wide variety of services, including "Surgery, Medicine, Obstetrics and Gynaecology, New-born and Paediatrics, Accident & Emergency, Radiology, and Pharmacy," and holds teaching and training for medical students (*Overview of GARH – Greater Accra Regional Hospital*). In addition to students and staff, the hospital also has a clinical engineering department that oversees the preventative and corrective maintenance of medical devices.

2.4 Medical Devices and Clinical Engineering

There is a plethora of technology that falls under the term "medical devices." According to Ghana's FDA Public Health Act 851, a medical device is:

> an instrument, apparatus, implement, machine, contrivance, implant, in vitro reagent, or other similar or related article, including a component part or accessory which is:

> recognized in the official National Formulary or Pharmacopoeia or a supplement to them, or intended for use in the diagnosis of disease or other condition, or in the cure, mitigation, treatment or prevention of disease in humans and animals." (Public Health Act, 2012)

What makes a medical device different from a drug is that the device may not be dependent on a chemical action within the body and may not have digestion necessary to perform its main function. (Public Health Act, 2012) With this definition, medical devices can range from a complex coronary stent to a simple tongue depressor.

Regardless of complexity, once these devices reach the hospital, the responsibility to maintain them falls on its team of biomedical engineers and clinical technicians. Clinical engineering is a subcategory of biomedical engineering, that focuses on device maintenance in hospitals (Grimes, 2003). Biomedical engineering units are responsible for the installation, management, and repairs of devices while clinical engineering units are responsible for ensuring "the availability of effective and efficient managerial and technical support for healthcare equipment and availability and maximum utilization of all healthcare equipment at all levels of healthcare delivery" (Amissah et al., n.d.). At the Greater Accra Regional Hospital, there is only a clinical engineering department. Their main responsibilities include device repairs, device maintenance, and device setup during surgery.

The prevalence of clinical engineers in Ghana can be mainly attributed to the country's sourcing of medical devices. Ghana relies heavily on imports for acquiring medical devices. Imports consist of 85% of Ghana's entire healthcare consumption (*Ghana - Medical Equipment/ Pharmaceuticals | Privacy Shield*, n.d.). Nearly all of Ghana's medical devices are imported into the country with little to no representatives from manufacturers there to maintain their devices

(Personal Communication, 2/15/2023). Not only are engineers in Ghana required to understand the workings of every single type of device as defined above, but they are also required to know variations in companies and models of each device. The expectation is that engineers are a walking database of device manuals, knowing all necessary information required to fix each device and set up equipment for surgeries.

One unique aspect of Ghanaian government is the requirement to complete a year of service. The National Service Scheme is a mandate that all Ghanaians between the ages of 40 and 18 must complete a year of service after tertiary courses are completed and approved. This is meant as a period of practical training before graduates seek out long-term employment (*Rules*, n.d.). At the Greater Accra Regional Hospital, the clinical engineering department hire people to complete their year of service. Within this year employees are trained in how to troubleshoot and manage broken equipment.

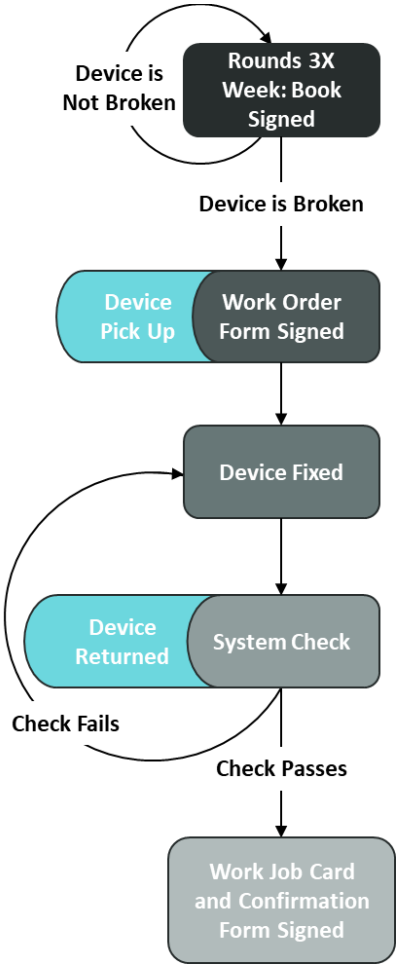
2.5 Prior Art

These are the current systems in place at the Greater Accra Regional Hospital's clinical engineering department. These processes are to report broken devices and maintain records of their repair in accordance with the GHS.

2.5.1 Current System

At the Greater Accra Regional Hospital, broken biomedical devices are reported through a system using paperwork and personal communication. An overview of the entire system is shown below.

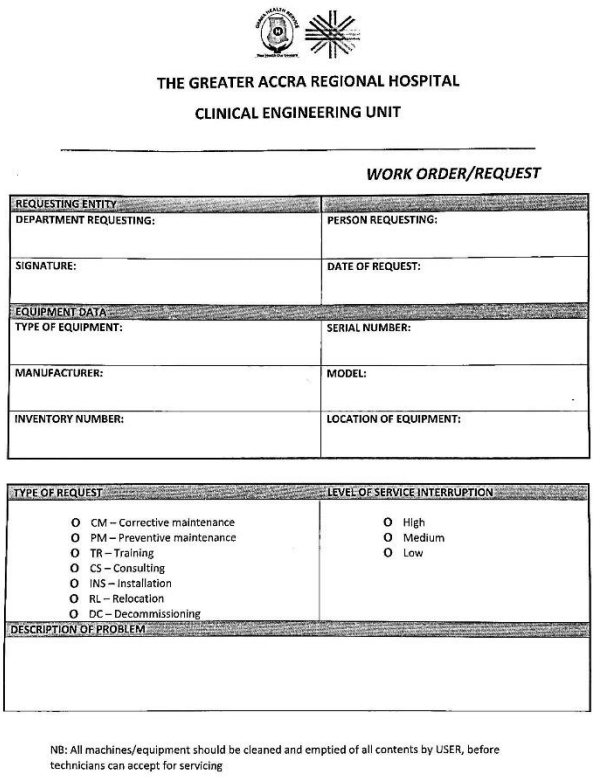
Figure 2: Flowchart of the Current Medical Reporting System



Three times a week, rounds are completed to check in with each department in the hospital and determine if there are issues with any devices. The engineering department has a record book for each level of the Greater Accra Regional Hospital. The team will divide into groups assigned to cover one or two levels for the day. The group will go to the head nurse of each department on that level to ask if there is any broken equipment. Regardless of whether there is an issue or not, each head nurse must sign the book confirming that the round was completed. If a device needs to be repaired in the engineering workshop, it is not taken from the unit until the Work Order/Request form is completed.

That is one of the three forms that are filled out by the clinical engineering department: the Work Order/Request form, the Work Report/Job Card, and the Certification of Work. The Work Order form is the form that officially opens a complaint with the clinical engineering department. This form takes note of the problem the user is facing, as well as information on the equipment, the requesting entity, request type, and level of service interruption, as seen below. It requires a signature from the person requesting the work. After these forms are completed and signed, they are photocopied and saved in an online record.

Figure 3: The Greater Accra Regional Hospital Work Order/Request Form



THE GREATER ACCRA REGIONAL HOSPITAL

CLINICAL ENGINEERING UNIT

WORK ORDER/REQUEST

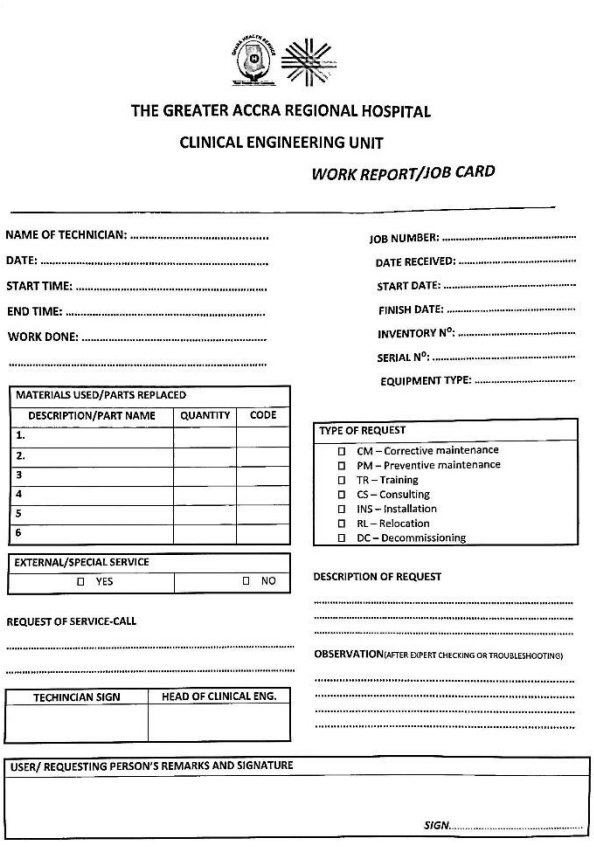
REQUESTING ENTITY	
DEPARTMENT REQUESTING:	PERSON REQUESTING:
SIGNATURE:	DATE OF REQUEST:
EQUIPMENT DATA	
TYPE OF EQUIPMENT:	SERIAL NUMBER:
MANUFACTURER:	MODEL:
INVENTORY NUMBER:	LOCATION OF EQUIPMENT:

TYPE OF REQUEST	LEVEL OF SERVICE INTERRUPTION
O CM – Corrective maintenance O PM – Preventive maintenance O TR – Training O CS – Consulting O INS – Installation O RL – Relocation O DC – Decommissioning	O High O Medium O Low
DESCRIPTION OF PROBLEM	

NB: All machines/equipment should be cleaned and emptied of all contents by USER, before technicians can accept for servicing

The Work Report/Job Card form serves as a record of the issue and the maintenance performed on the device and notes any replacement parts used. It requires a signature from both the technician who worked on the device and the head of the clinical engineering department.

Figure 4: The Greater Accra Regional Hospital Work Report/Job card



THE GREATER ACCRA REGIONAL HOSPITAL

CLINICAL ENGINEERING UNIT

WORK REPORT/JOB CARD

NAME OF TECHNICIAN: .....

DATE: .....

START TIME: .....

END TIME: .....

WORK DONE: .....

.....

JOB NUMBER: .....

DATE RECEIVED: .....

START DATE: .....

FINISH DATE: .....

INVENTORY N^{O}: .....

SERIAL N^{O}: .....

EQUIPMENT TYPE: .....

MATERIALS USED/PARTS REPLACED		
DESCRIPTION/PART NAME	QUANTITY	CODE
1.		
2.		
3		
4		
5		
6		

EXTERNAL/SPECIAL SERVICE	
☐ YES	☐ NO

REQUEST OF SERVICE-CALL

.....

.....

TYPE OF REQUEST
☐ CM – Corrective maintenance
☐ PM – Preventive maintenance
☐ TR – Training
☐ CS – Consulting
☐ INS – Installation
☐ RL – Relocation
☐ DC – Decommissioning

DESCRIPTION OF REQUEST

.....

.....

.....

OBSERVATION(AFTER EXPERT CHECKING OR TROUBLESHOOTING)

.....

.....

.....

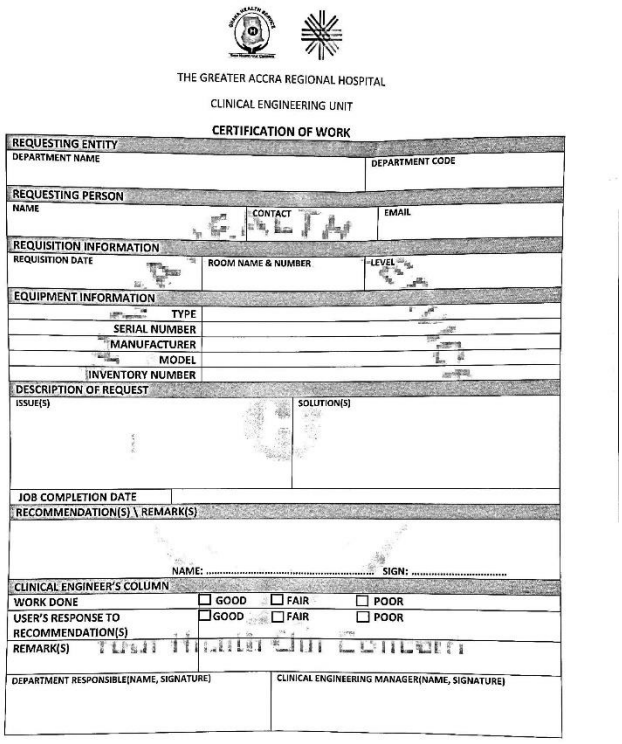
.....

TECHINCIAN SIGN	HEAD OF CLINICAL ENG.

USER/ REQUESTING PERSON'S REMARKS AND SIGNATURE
SIGN.....

Finally, the Certification of Work form describes the issues, solutions, and recommendations, as well as the equipment information and request information. It requires a signature from both the head of the requesting department, and the clinical engineering manager.

Figure 5: The Greater Accra Regional Hospital Certification of Work



THE GREATER ACCRA REGIONAL HOSPITAL

CLINICAL ENGINEERING UNIT

CERTIFICATION OF WORK

REQUESTING ENTITY		
DEPARTMENT NAME		DEPARTMENT CODE
REQUESTING PERSON		
NAME	CONTACT	EMAIL
REQUISITION INFORMATION		
REQUISITION DATE	ROOM NAME & NUMBER	LEVEL
EQUIPMENT INFORMATION		
TYPE		
SERIAL NUMBER		
MANUFACTURER		
MODEL		
INVENTORY NUMBER		
DESCRIPTION OF REQUEST		
ISSUE(S)	SOLUTION(S)	
JOB COMPLETION DATE		
RECOMMENDATION(S) \ REMARK(S)		
NAME: ..... SIGN:		
CLINICAL ENGINEER'S COLUMN		
WORK DONE	☐ GOOD ☐ FAIR	☐ POOR
USER'S RESPONSE TO RECOMMENDATION(S)	☐ GOOD ☐ FAIR	☐ POOR
REMARK(S)		
DEPARTMENT RESPONSIBLE(NAME, SIGNATURE)	CLINICAL ENGINEERING MANAGER(NAME, SIGNATURE)	

Additionally, according to the Ghana Health Service, it is the responsibility of the hospital staff to "report equipment faults, damage or unsatisfactory performance to the clinical engineering officer" to ensure proper use of equipment (*Medical Equipment Policy and Guidelines*). This means that the responsibility to report faulty equipment lies with the staff using the equipment.

2.5.2 CEU App System

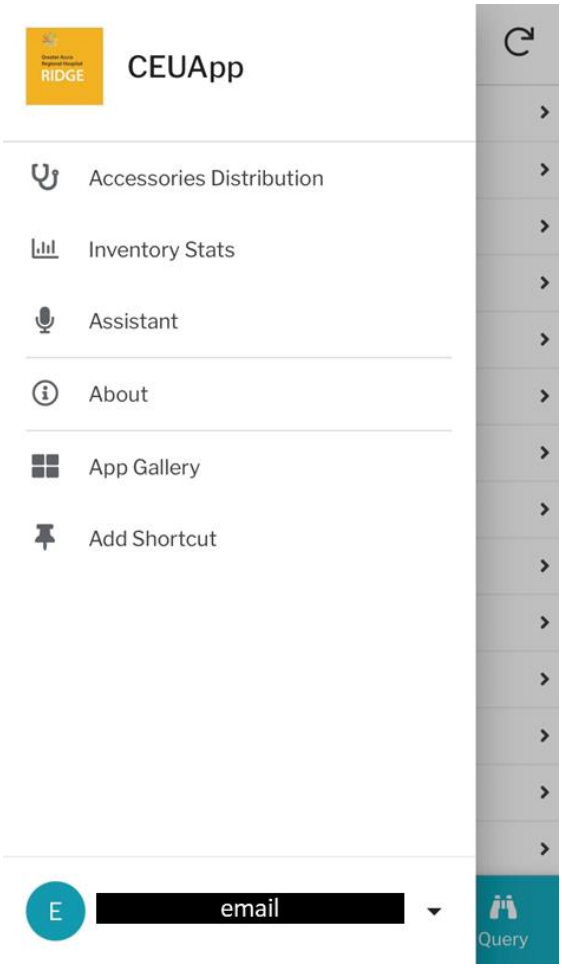
Previously, an app was made by the head of the engineering department at the Greater Accra Regional Hospital to assist in the medical device reporting system. The application was created using AppSheet, a Google extension that allows users to create an application with no

coding. Through this app, users can log in through their google accounts and data can be acquired through google sheets (*Google AppSheet | Build Apps with No Code*, n.d.).

The AppSheet created for the engineering department at the Greater Accra Regional Hospital contained features that allow the department to keep track of forms and inventory. Currently the app is only used by the engineers at the hospital. This does not include those completing their year of service, as they are not trained to use the app and it is a pay-per-user agreement with AppSheet. For this reason, the head nurses also do not have access to this app.

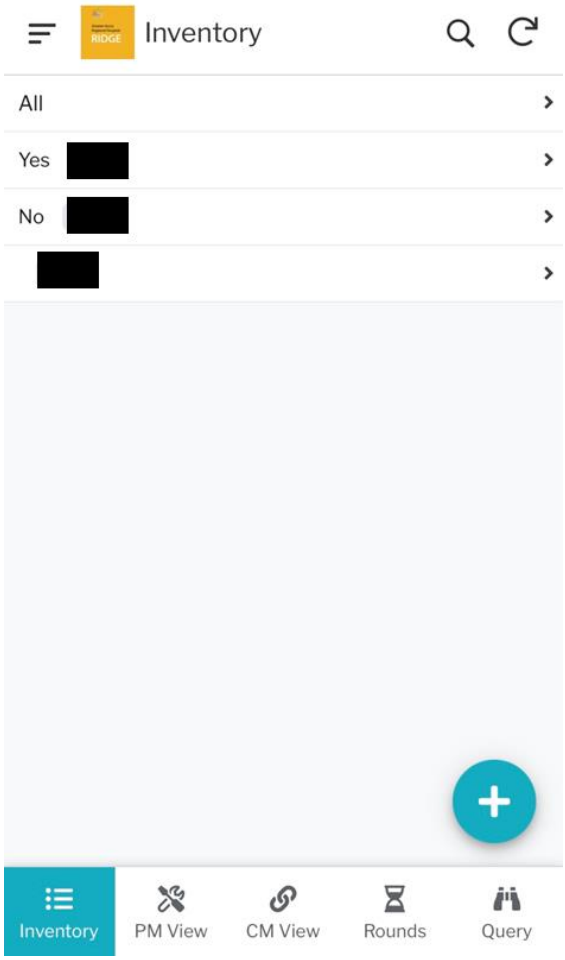
The picture below shows the side bar available when clicking on the hospital logo on the app.

Figure 6: CEU App Side Tabs



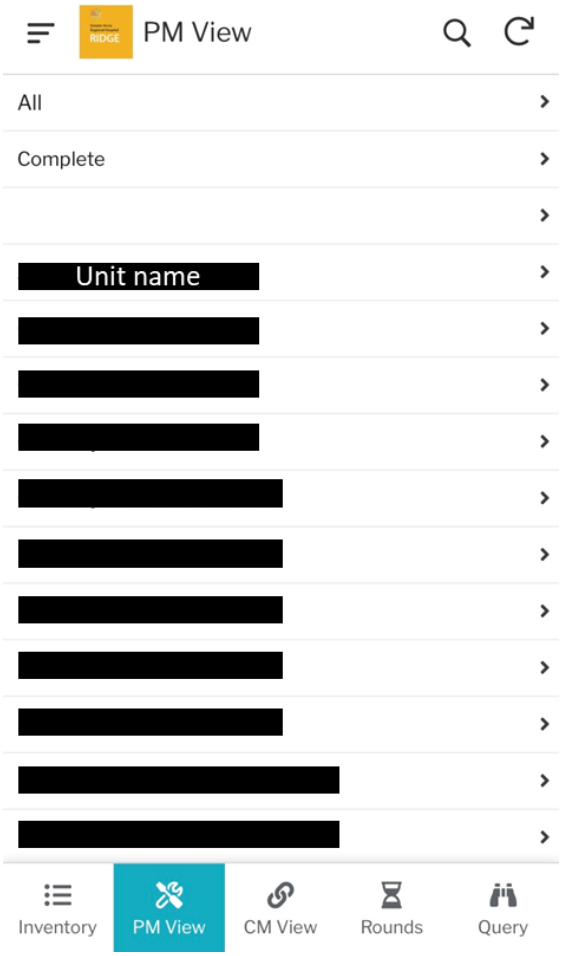
On the bottom bar of the app's homepage, there are five tabs available. The first tab is the Inventory section which shows all devices that are in stock (yes) or out of stock (no).

Figure 7: CEU App Inventory



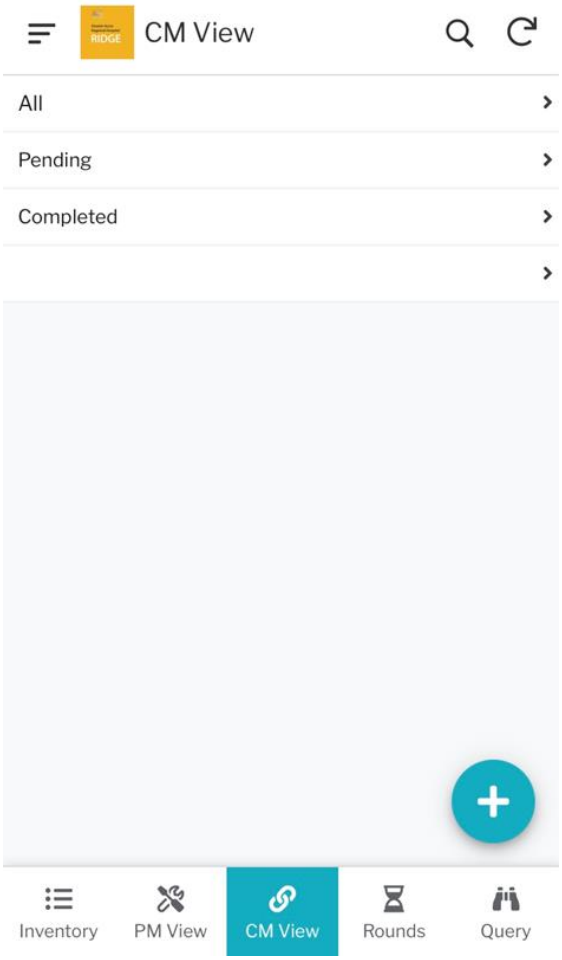
The next tab is the PM View, which stands for Preventative Maintenance. This is for work orders completed for scheduled device system checks and is completed regardless of whether the device needs repair. These reports can be filtered by the unit they are completed in.

Figure 8: CEU App PM View



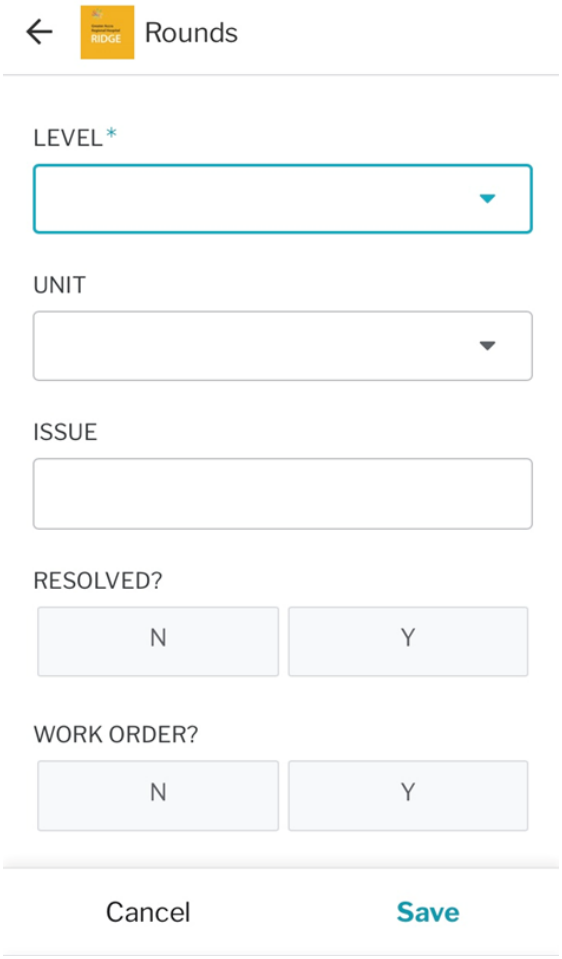
The CM View tab stands for Corrective Maintenance. This is where all pending and completed work order forms can be found.

Figure 9: CEU App CM View



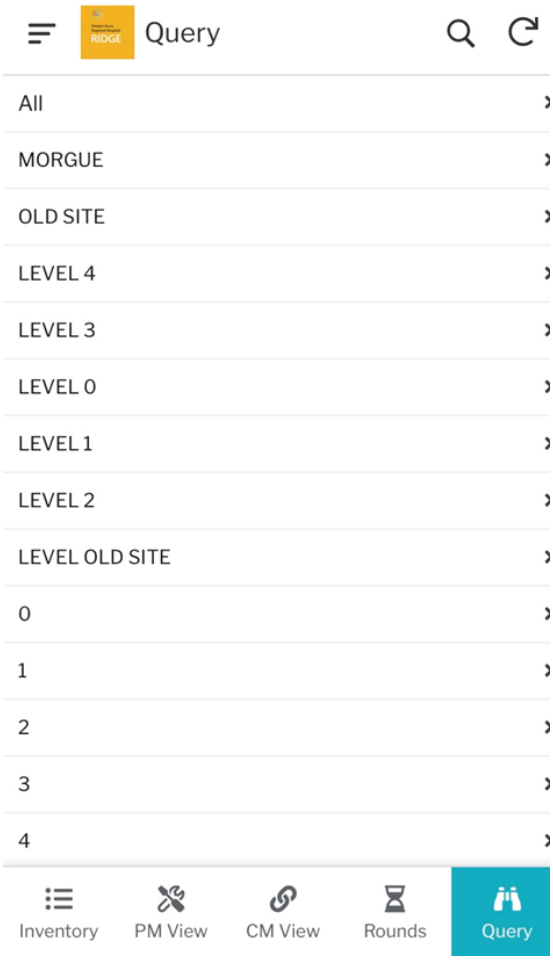
The rounds tab is where work order forms can be completed on the app. This feature is used to electronically track the data for each request and update the forms as needed. Since the head nurses do not have access to this app, they cannot see any progress tracked here.

Figure 10: CEU Rounds View



The Query View allows users to look at all equipment being used in the hospital by location of that equipment. Once a device is chosen, users have access to detailed information about the device, such as model and serial number.

Figure 11: CEU App Query View



The goal of this app was to be used as a new system for device reporting. Due to cost, nurses not having access to the app, and the need for training new users, the app is mainly used by the head of the clinical engineering department for data tracking.

2.6 Lightwave Health Information Management System

The Lightwave Health Information Management System (LHIMS) is the system that the Greater Accra Regional Hospital uses to manage patient records. It is provided by the Ministry of Health and is currently being implemented in hospitals and healthcare centers across Ghana. This allows the data from patients to be available across multiple facilities (*Lightwave EHealthcare*

Solutions). This system is focused on patient data and does not include any information about medical equipment. Each employee has an ID which they can log onto the system, but they cannot communicate with each other on the system and are only able to log in to access data.

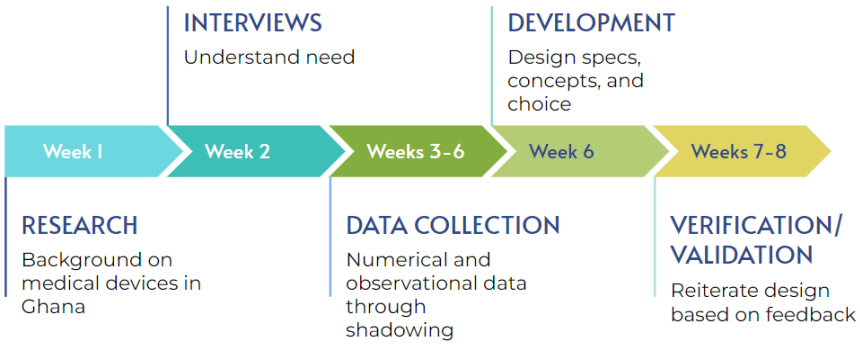
Chapter 3: Project Approach

This project is multifaceted, so this chapter examines all the factors that needed to be considered for this project to be successful.

3.1 Project Strategy

The methods for this project were scheduled so that completion could occur within the 8 weeks that we were in Ghana. The figure below shows a general schedule for the project.

Figure 12: Overview of Project Strategy



The first week was focused on doing the background research necessary for understanding the workings of the health care sector and medical device regulations in Ghana. In the second week, interviews were conducted to get a better understanding of the needs that this project seeks to address. After these interviews, data collection was performed through the

shadowing of the clinical engineering department at the Greater Accra Regional Hospital. Using the data collected, development began on the design specifications and design concepts in week six. Once a design had been chosen, the verification/validation process was performed by developing a conceptual model of the design and reiterating it based on the feedback received.

3.2 Client Needs

Initial and revised client statements and client needs are described below.

3.2.1 Needs Statements

Before landing in Ghana, the project was meant to focus on broken donated medical equipment in Ghana that can accumulate in hospitals without being used or refurbished. Therefore, our initial client statement is as follows:

> Ghana is in need of a solution to broken medical devices where there is little/difficult access to replacement parts and new equipment is expensive. We hope to create a medical device refurbishment system manual that will utilize pre-existing resources to create safe and effective medical equipment.

After connecting with employees at the Greater Accra Regional Hospital, we discovered that there is not a huge need for dealing with replacement parts and there is not a stockpile of broken devices that are not utilized. Through working with clinical engineering and observing rounds our needs statement changed to focus on the system of reporting devices. Considering these findings, our client statement was revised to the following:

> There is a need for a new medical device reporting system at the Greater Accra Regional Hospital that will improve communication between nurses and clinical engineers and minimize pressure and time on the clinical engineering department.

3.2.2 Interviews & Observational Data

This project is based on an ethnographic approach. The necessary components of the project were discovered through client interviews and shadowing of the clinical engineering department at the Greater Accra Regional Hospital. The summary of the client interviews is shown in the table below.

Table 1: Client Interviews Summary

Name	**Profession**	**Main Takeaway**
Dr. Bannor	President of Health Facilities Regulatory Agency (HeFRA)	Broken medical devices are a common issue in Ghanaian hospitals. Connected team with the Greater Accra Regional Hospital.
Dr. Emmanuel K. Srofenyoh	CEO GARH, Obstetrician	Sometimes devices are broken due to user error and improper maintenance. The clinical engineering department at GARH handles all broken medical equipment. Connected team with Joseph Ashie.
Joseph Ashie	Head BME GARH	The clinical engineering department is understaffed. All of the head nurses are familiar with Joseph and often call him about their broken equipment or the need for new equipment. Joseph has the responsibility of repairing devices, tracking the department's inventory, maintaining equipment during surgeries, and training those completing their year of service.
Year of Service Workers at CEU	Recently Graduated Engineers	BME education in Ghana focuses a lot on theory and design. Service workers didn't begin to learn device repair until they arrived at GARH.
Richard	IT GARH	It would be difficult to integrate a system into the LHIMS.

The current system for reporting broken biomedical devices in the hospital is for the engineers to go to the head nurse of each department in the hospital and record any broken

devices in a notebook. This notebook is then brought back to the clinical engineering department, and the broken devices are reported to the head of the clinical engineering department. From there, the head of the engineering department validates each report and starts a work order for the device. Even when the work is divided by floor, this system is time-consuming because of the number of departments and the time it takes walking between them. Additionally, it takes time to report all the devices to the head of the department. At one time, an app was used in place of a notebook to input the work orders, but the new engineers have yet to be trained on using the app. The app is also limited to cell phones, and is priced per user, making it costly to implement on a larger scale. These issues create more work for the clinical engineering department and take time away from the devices themselves. These issues are explored in further detail below, broken down by different clients.

3.2.3 Engineering Department

The current system requires a significant amount of time for the engineers to complete rounds, which is time that could be used for more relevant work. An ideal system would eliminate the time it takes to complete rounds altogether, as well as minimizing the time it takes for a broken device to been seen by the engineering department, as the reports can come in real time. Another major concern to be addressed is communication between nurses and engineers. Currently, after a device has been reported as broken, there is no consistent method of communication between the nurses and the clinical engineering department for updates on the device. There is a need for a system that allows the nurses to receive progress updates from the engineers to increase communication between the two departments.

Secondary needs that the system would have to address include minimizing the number of complaints the head of the engineering department receives via phone call and allowing the reports to be sorted by importance.

3.2.4 Nurses

The main priority of each department's head nurses is getting their equipment running as soon as possible. Sometimes when a work order was placed during rounds, the device was not yet fixed by the next time rounds are completed. This caused frustration with the head nurses during rounds since when they were asked if there were any issues, they complained about the issue they had in previous rounds that was not fixed. Encounters such as this resulted in a lack of trust from the nurses that the engineers completing their year of service will communicate the nurses' issues with the head of the BME department.

3.2.5 Management

The medical reporting process produces a lot of data that could be valuable to management. This data could be better utilized to identify common issues with device categories, companies, and models, that could guide the hospital's purchases. Data around the cause of device malfunctions can result in new training to guide users. Since the project was focused on the Clinical Engineering Department, we did not get a chance to speak to the hospital's procurement department, but data from management would serve as a guide.

3.3 Technical Design Requirements

Based on the previously stated client needs, the following technical design requirements have been created. These guide the development of the design options.

3.3.1 Objectives

The objectives of this project are to improve efficiency of the reporting system, create a system for updating nurses on progress, and a way to request equipment. Because the broken device reporting system currently relies on walking around the hospital and checking with each department, it is a time-consuming process for the clinical engineering department. The primary goal is to cut down on the amount of time spent on the reporting process.

3.3.2 Constraints

This project must adhere to the necessary standards of reporting according to Ghana Health Services. This creates a constraint on what information is included in the form created and how the reporting system operates. Additionally, any designs related to Lightwave Health Information Management System (LHIMS) would be required to go through the necessary channels to be implemented. Though the LHIMS system is mandated by the Ghana Health Service, it is operated by an international company, making integration with this system difficult. The hospital management would need to make a proposal to the Ghana Health Service who, if approved, would suggest the changes to Lightwave eHealthcare Solutions, the owner of LHIMS. This would be a very long process for approval and implementation.

The main constraint on this project is time. For this project to be successful it had to be completed in the eight weeks that we had on the ground. Much of this time was used for introductory interviews, project discussions with faculty at the hospital, hours shadowing the engineering department, project development, and design verification/validation.

3.3.3 Functions

The system for the reporting of medical devices relies on two main subsystems, which relate to two separate clients: the clinical engineering department and the head nurse of each

department. The head nurse of each department is responsible for reporting any device that has an issue, and signing necessary paperwork to confirm that the issue has been acknowledged and has been fixed. The clinical engineer has the responsibility of receiving the work order, bringing the device to the workshop, fixing the device, and signing necessary paperwork to confirm that the issue has been acknowledged and has been fixed. The functions of the two subsystems in this operation can be best described as facilitating a relationship with these two clients. In this case, success relies on proper communication and a structured system that both clients are aware of.

On the backend, there is a third subsystem for the management that works separately from the clinical engineering department and the nurses. The management should have access to any data generated from the paperwork if needed.

3.3.4 Specifications

The specifications for this system rely heavily on client interviews and observations. Being on the ground participating in rounds and speaking with people working in the hospital provided insight on concerns and possible features that may be useful for the system. Based on these observations the following specifications were deemed necessary for our design:

1. **Proper Communication:** The system should improve communication between the head nurses and the engineering department.
2. **User Friendly:** The system needs to be simple to navigate and easy for all users to learn. Otherwise, no one will have a desire to pick up the new system, causing more complaints than the current system.
3. **Secure**: The system must be secure as it relates to medical data. Only those who need to use the system should have access to it. The data collected on the medical devices and

their issues should be safely stored and made available to the engineering department head and hospital management.

4. **Time Efficient**: The system must be efficient and reduce downtime. Decreases in the time between a device being broken and returned to operation in the unit, the time it takes for rounds to occur, and the amount of time that the engineers spend talking on the phone about issues should be seen. This specification allows the engineers to have more time to focus on getting the device functioning as soon as possible.
5. **Accurate:** The system should allow for data on devices and issues to be accurate.
6. **Accessible**: All components of the system must be easy to find. If the system is digital, it should have a quick link and if non-digital, components should be in a central standard location. The system itself should be accessible on computers, phones, and tablets.
7. **Affordable**: The system must be affordable for the hospital. Any costs related to service and maintenance of the system should also be accounted for.

3.3.5 Pairwise Comparison

In order to prioritize product specifications, a pairwise comparison of the specifications was made. The results of this comparison show that the most important specification for the design is improved communication between the nurses and engineers (highlighted in blue). The next most important features were usability and security, which were tied for second. Time efficiency and accurate data transfer resulted in a similar weight to the second most important specifications. Accessibility and affordability were deemed to be the least important specifications. While all specifications are necessary considerations for the design of the system, this method guided our choice in product design.

Table 2: Pairwise Comparison of Product Specifications

	User Friendly	Time Efficient	Affordable	Easily Accessible	Accurate Data Transfer	**Proper Communication**	Security
User Friendly		0	0	0	0	1	1
Time Efficient	1		0	0	0	1	1
Affordable	1	1		1	1	1	1
Easily Accessible	1	1	0		1	1	1
Accurate Data Transfer	1	1	0	0		1	0
Proper Communication	0	0	0	0	0		0
Security	0	0	0	0	1	1	
Sum	**4**	**3**	**0**	**1**	**3**	**6**	**4**

3.4 Standards

The standards of this project are according to the definitions provided by the Ghana FDA Public Health Act described in Chapter 2.4 Medical Devices and Definitions and the standards of reporting explained in detail in Chapter 2.5 Prior Art.

Chapter 4: Design Process

This chapter details the various designs produced to meet the technical design requirements, the comparisons performed to determine the best design, and the final design chosen.

4.1 Design Option 1: Basic Website Form

The first design option is to develop a basic website containing the work order form so that all requests can be made digitally. This would allow nurses to fill out a request for a broken device and the engineers to receive the request on their computers. The website form would minimize the need for the engineers to do rounds three times a week. Engineers would have the

option to complete rounds to check in with the departments, but they would not be necessary since any device issues would be filled out online.

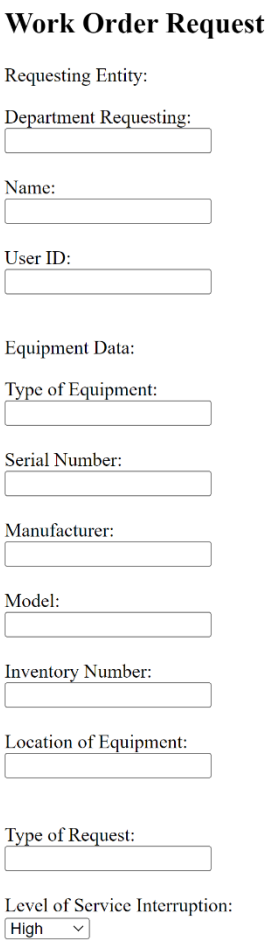
This would be done using HTML coding with PHP to supplement. The code would be uploaded to a local server at the hospital and hosted on a free website platform. Below is a sample of preliminary code to design a basic form in HTML.

Figure 13: HTML Code for a Work Order Request Form

```
<!DOCTYPE html>
<html>
<body>

<h2>Work Order Request</h2>
  <p>Requesting Entity:<p/>

<form action="Data.php" target="_self" method="post">

<label for="department">Department Requesting:</label><br>
    <input list="department" required>
 <datalist id="department">
   <option value="A">
   <option value="B">
   <option value="C">
   <option value="D">
   <option value="E">
 </datalist><br><br>

  <label for="name">Name:</label><br>
  <input type="text" id="name" name="name" required><br><br>

  <label for="userid">User ID:</label><br>
  <input type="text" id="userid" name="userid" required><br><br>

  <input type="hidden" id="date" name="date" value=datetime>

  <p>Equipment Data:<p/>

  <label for="type">Type of Equipment:</label><br>
  <input type="text" id="type" name="type" required><br><br>

  <label for="serial">Serial Number:</label><br>
  <input type="text" id="serial" name="serial" required><br><br>

  <label for="manufacturer">Manufacturer:</label><br>
  <input type="text" id="manufacturer" name="manufacturer" required><br><br>

  <label for="model">Model:</label><br>
  <input type="text" id="model" name="model" required><br><br>

  <label for="inventory">Inventory Number:</label><br>
  <input type="text" id="inventory" name="inventory" required><br><br>

  <label for="location">Location of Equipment:</label><br>
  <input type="text" id="location" name="location" required><br><br><br>

<label for="requesttype">Type of Request:</label><br>
    <input list="requesttype" required>
 <datalist id="requesttype">
   <option value="CM - Corrective Maintenance">
   <option value="PM - Preventive Maintenance">
   <option value="TR - Training">
   <option value="CS - Consulting">
   <option value="INS - Installation">
   <option value="RL - Relocation">
   <option value="DC - Decommissioning">
 </datalist><br><br>

   <label for="level">Level of Service Interruption:</label><br>
 <select id="level" name="level" required>
   <option value="high">High</option>
   <option value="medium">Medium</option>
   <option value="low">Low</option>
 </select><br><br>

  <label for="description">Description of Problem:</label><br>
  <textarea name="description" style="width:500px; height:200px;" required></textarea><br><br>

<input type="submit" value="Submit">
</form>

</body>
</html>
```

This code produces the following website. This is a basic proof of concept for a website, which would be made more robust if chosen as the design concept.

Figure 14: HTML Webpage for a Work Order Request Form



This option would require space on a local server in the hospital, or space on a larger server if the system were to be scaled up for multiple hospitals.

4.2 Design Option 2: LHIMS Integration

The next design option is to develop an add-on to the LHIMS system that the hospital currently uses. The add on would consist of an online version of the work order form which nurses could use to report an issue by logging into the system already used by the entire hospital. Similar to option one, this would minimize the need for engineers to do rounds three times a week since all requests would be completed and received by the engineers digitally. The LHIMS

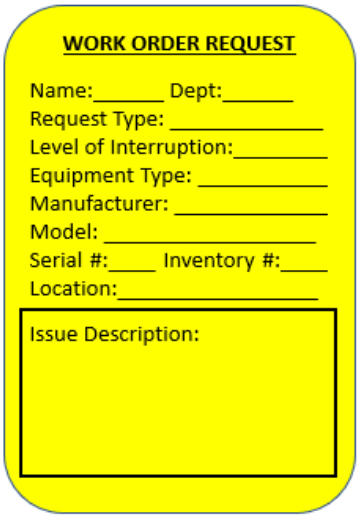
integration would also minimize the need for any additional software to be added to the computers and users would not need to remember a link to a form. The main benefit to this design is that LHIMS is not only used at the Greater Accra Regional Hospital, but all hospitals in Ghana.

However, in order to integrate this add-on into LHIMS, a proposal would need to go through the proper channels. This would entail going through the clinical engineering department, then the management of the hospital, then the Ghana Health Service, then to the Ministry of Health, which would then coordinate with Lightwave eHealthcare Solutions. According to the head of the clinical engineering department, by the time the hospital would hear back from Lightwave, “Jesus would have come, and we’d be on our way to heaven” (Personal Communication, 02/15/2023).

4.3 Design Option 3: Tagging System

The tagging system is a design that does not rely on the internet to report medical devices. If a device has an issue, the head nurse would place a tag on the device. The tag would act as the work order form, where the nurse could fill out all information about the device. Instead of bringing the book to be signed, rounds would be used to investigate and pick up any tagged devices. This system would decrease time by eliminating the need to sign the book, but engineers would still need to make rounds to go to each department and check for any issues. The main concern for using this design is that it does not contribute any benefit to the highest ranked product specification: communication. Shown below is a sample of what a device tag might look like.

Figure 15: Sample Work Order Request Tag



This device tag would include information that is found on the work order request forms and provide the engineers with a quick reference for the form.

4.4 Design Option 4: Web Application

This design option is to create an application that can be used on a phone or computer. This would be a robust system with multiple pages on the nurses' side to make reports of broken devices, track repair progress, as well as request additional equipment. On the clinical engineer's side, they would be able to see a spreadsheet of the reports, sort by completed or pending requests, maintain digital records, update report progress, and track trends overtime. Further functionality could be added to include a device manual database and training for the technicians. The nurses and engineers/technicians would be required to log into the system to track who creates and updates reports.

This design differs from design option 1 primarily because of the login requirements as well as the scale. While option 1 could be scaled up to some degree, this design would be easily available to anyone with internet access. One drawback of this design is the time it would take to develop and implement it.

4.5 Concept Comparison

Here is a comparison of the four design options using different comparison methods to determine the best design choice.

4.5.1 Pugh Matrix

Shown below is a Pugh Matrix analysis of the four design concepts compared to the current system against the weighted product specifications.

Table 3. Pugh Matrix of Design Concepts

	Weight	Current System	Basic Website Form	LHIMS Integration	Tagging System	**Web Application**
User Friendly	5	0	1	1	0	1
Time Efficient	4	0	1	1	1	1
Affordable	1	0	0	-1	-1	0
Easily Accessible	2	0	-1	1	0	1
Accurate Data Transfer	3	0	0	1	0	1
Proper Communication	6	0	1	1	-1	1
Security	5	0	1	1	0	1
Total		**0**	**18**	**24**	**-3**	**25**

The Web Application concept design, highlighted in blue, performed best. It is worth noting that while the LHIMS integration was close behind, this analysis did not consider the amount of time it would take to implement such a system.

4.5.2 Competitive Analysis

A competitive analysis of the current systems and the winning design from the Pugh Matrix, the web application, is shown below.

Table 4: Competitive Analysis of Winning Design and Current Systems

	Weight	Current System	AppSheet	**Web Application**
User Friendly	5	0	1	**1**
Time Efficient	4	0	-1	**1**
Affordable	1	0	-1	**0**
Easily Accessible	2	0	-1	**1**
Accurate Data Transfer	3	0	1	**1**
Proper Communication	6	0	0	**1**
Security	5	0	1	**1**
Total		0	6	**25**

Again, the web application, highlighted in blue, performed best, demonstrating a clear improvement on the other current systems.

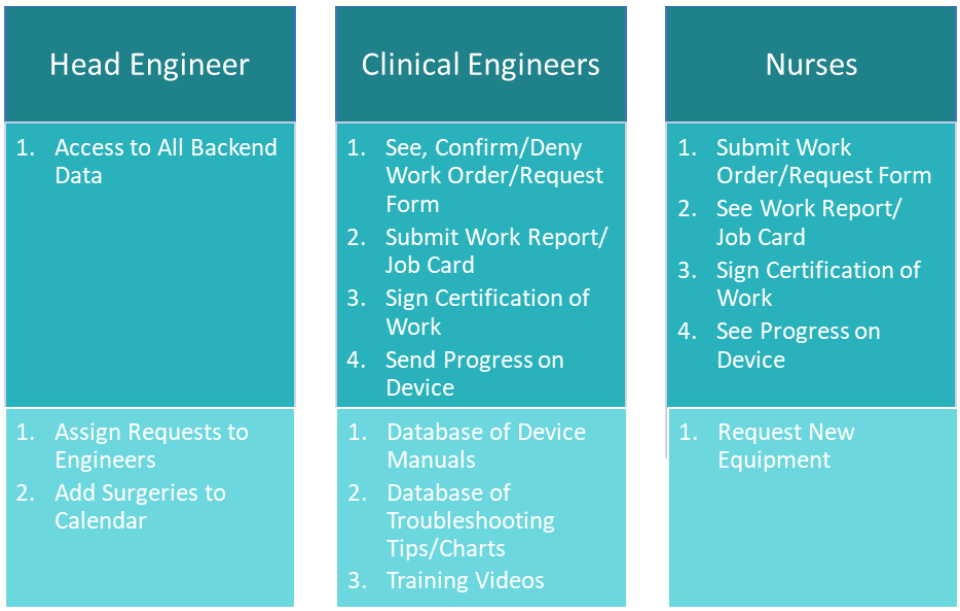
4.6 Final Design Selection

Based on the comparisons made, the web application was selected as the final design. It is the best match in terms of product specifications when compared to the other design concepts and outperformed the current systems as well. It is user-friendly, time efficient, easily accessible, performs accurate data transfer, facilitates proper communication and is secure. It is comparable to the current system in terms of affordability.

Due to time constraints, this system will not be fully developed and implemented at this time. The final deliverable will be a comprehensive proposal for the Greater Accra Regional

hospital detailing the design and features to meet the product specifications. This will be expanded upon in the Conclusions and Recommendations section. Shown below is a sample of the proposed features, by subsystem, organized by order of importance.

Figure 16: System Features for Main Stakeholders in Order of Importance



The top section is the features that are necessary to meet product specifications and the bottom section shows features that are less necessary but would be beneficial to include.

Chapter 5: Design Verification

Because there is no physical product, much of the design verification is hypothetical. Nonetheless, each subsystem was evaluated as best as possible.

5.1 Engineer Subsystem

Based on observations, the time it takes for rounds to be completed averages 68.5 minutes. The proposed system would eliminate the need for rounds altogether, reducing this

number to zero. The engineers would have over an hour of their day back, and the efficiency of the reporting system would dramatically increase. This may have further positive impacts on the system as engineers have more time to work on fixing devices, speeding up that part of the process as well.

Creating a system with progress update capabilities built into the system would make it easier for engineers to communicate any updates with nurses. The main concern with this system would be engineers not inputting updates or forgetting to do so. To combat this, the system for providing updates should be as simple as possible, ideally done with the click of a button.

In terms of the secondary needs, designing such a reporting system would eliminate the need for nurses to directly call the head of the engineering department, as reports can be made any time of the day. So long as nurses receive notifications that their requests have been seen, they would likely not feel the need to call. Additionally, a digital system would allow for more efficient sorting of reports than a physical book.

Finally, as further validation from the engineers' perspective, the concept was presented to the head of the engineering department for feedback. Small additions were made to the concept based on the feedback received. Overall, the feedback received was positive.

5.2 Nurse Subsystem

As the communications between the engineers and nurses are linked, improving the communication on the engineering side will improve communication with the nurses as well. Once the nurses have adjusted to the interface, they will be able to make requests as needed instead of waiting for rounds. This also helps to ensure that no broken devices are missed on rounds because they have been forgotten after a day. Additionally, the feature that allows nurses

to request equipment would reduce the need for the nurses to call the head of the engineering department.

5.3 Management Subsystem

The ability to track long term trends in the data will allow the management to make more informed decisions on what devices to purchase based on their performance. Using this data, they can accurately estimate the rate of return on comparable devices of different models based on their longevity.

5.4 Future Verification

Because there is little concrete verification that can be done at this stage, recommendations have been created for future verification of the system. Once the system is created, it should be integrated first into a single unit to undergo testing. As with the creation of the system, collaboration with the clients is crucial to the success of the system. At this stage, once the system has been designed, the client focus would shift from the nurses to the engineers. Any head nurses that are willing to participate would provide feedback on the ease of use of the system. With this feedback in mind, the system would be modified as needed then retested. This process would continue until the nurses are satisfied with the interface. The system would then be implemented throughout the hospital in phases to ensure that there are no further issues.

Chapter 6: Final Design Validation

The method of verification was analyzed to ensure the overall requirements were met. The design impacts are also discussed in this chapter.

6.1 Validation Method Analysis

It can be concluded that this project did meet all the objectives stated in Chapter 3. If the proposed system were to be implemented, the medical device system's efficiency would be improved as it will result in decreased time between the issue being reported to being fixed, and decreased time for the head of the engineering department to be communicating with nurses on complaints. This design adheres to the main goal of giving the engineering department more time to focus on device repair through better communication and efficient reporting.

The next objective, to create a system for updating nurses on progress, is also satisfied through this design. The proposed application contains a series of stages in the repair process, of which nurses can easily be notified by engineers. This feature aligns with the product specification that was deemed to be the most important: proper communication between nurses and engineers.

The final objective, to create a way to request equipment, was also addressed. This feature was deemed to be a non-necessary but beneficial component to our design. After learning more about the engineering department's capabilities and responsibilities, it was discovered that it is the nurses' responsibility to request new equipment and the engineering department can only offer new equipment if it is already in stock at the hospital.

6.2 Proposal Verification

The proposal was reviewed by a computer science student at WPI to ensure that the proposal included all the necessary information to design the application. Based on feedback from the student, some minor additions were made to the proposal to provide helpful information for anyone using the proposal as a guide. Ideally, the proposal will be given to a future computer

science MQP team at WPI. This verification step is important to allow for a smooth transition of the project during implementation.

6.3 Design Impact

This design was created based off personal interactions with users and stakeholders. The ability to be on the ground experiencing the current hospital system allowed our design to be personalized to the clients' needs. The proposed system adheres to all the previously stated objectives and product specifications.

Even if the necessary features of the proposed system are the only ones implemented, the design will have a positive impact on the hospital by providing a more efficient system for medical reporting. Digitalizing the forms for medical device reporting immediately improves time efficiency by minimizing the need for engineers to make rounds to each unit and ask if there are any issues. It further improves efficiency for the hospital, by creating a space to record all data on the hospital inventory, which could guide future purchases. The digital system also minimizes the need for the purchase and waste of paper products, adding environmental value to this design. The progress report feature impacts the relationship between nurses and engineers by increasing communication in an effective manner.

The design works to bring out the common goal that nurses and engineers have always had: to provide patients with the best care.

6.3.1 Economics

In terms of economic impacts, this design increases the efficiency of the clinical engineering process at the hospital, therefore improving the overall efficiency of the hospital by having better turnaround time for broken devices. Additionally, the feature that gives managers

access to data on the longevity of devices will allow for more informed purchasing of devices that will last longer and perform better. This will save the hospital money over time.

6.3.2 Environmental Impact and Sustainability

Because this design is built for a paperless system, it will allow the clinical engineering department to slowly phase out their paper-based system of tracking work orders. This will reduce the amount of paper waste produced by the hospital. However, as it is an electronic system, it may increase the amount of electricity used by the hospital, which may not be supplied by renewable energy. The system also needs to be hosted on a server, either locally or externally, which also requires electricity and storage space for the data produced.

6.3.3 Societal Influence

This system directly benefits the clinical engineers, nurses, and management at the hospital. It will also indirectly benefit all the patients of the hospital as the care is improved, bringing a positive influence on society with the improvement in healthcare.

6.3.4 Political Ramifications

Should this system be implemented in multiple hospitals across Ghana or be adopted by the Ministry of Health like the LHIMS system, it would improve the quality of healthcare across the country. The increase in efficiency for clinical engineering departments would reduce the number of devices out of service at any given time and help to reduce the stress on the clinical engineers.

6.3.5 Ethical Concerns and Health and Safety Issues

Because this system is not a physical product, there are fewer ethical concerns than a standard product. It is not a patient facing system, so there are little ramifications in terms of

patient well-being. The main interactions are with the clinical engineers and the nurses, and the flexibility of the system should allow for changes to meet any unique needs of either group.

Chapter 7: Discussion

A conceptual web application was designed to meet the needs of the clinical engineers, nurses, and the management of the hospital. Due to the time constraints and our lack of expertise with coding, a fully functional application was not created, only a conceptual model. Because of this, it was difficult to get concrete data for validation of the system. However, through interviews and interactions with the hospital staff, we determined that the features of our design meet needs that are currently not addressed. Additionally, because it is not a patient-facing or paper-based system, it has very little potential for negative ramifications.

Chapter 8: Conclusions and Recommendations

Through literature review and interviews with doctors and staff at the Greater Accra Regional Hospital, we were able to get a clear picture of the needs and requirements for an improved system of reporting broken biomedical devices. We divided the needs into different subsystems for the clinical engineers, nurses, and management. Technical design requirements were developed based on these needs. From the design requirements, four concepts were presented and compared against each other and the prior art. From the comparisons, the design was chosen that best fulfilled the clients' needs and the design requirements.

The design meets the objectives stated in section 3.3.1. It increases efficiency of the clinical engineering process, allows nurses to be updated on progress and improves communication between nurses and engineers, and allows for additional features like requesting equipment.

A comprehensive proposal was designed for the head of the clinical engineering department to describe what the design would look like. The proposal designed (as seen in Appendix A) will serve as a guide for a future team to continue the work that we started. This concept is well suited to be picked up by a computer science MQP team at WPI. The IT department had expressed interest in working with more students from WPI so the team would have additional technical support at the hospital, in addition to the clinical engineering team. Ideally the team would begin development in A and B term, then come to Ghana for the implementation and verification/validation processes in C term with the other project groups.

This concept has the potential to positively impact the hospital staff and, by association, the patients. In the future, we hope to see this design come to life in the Greater Accra Regional Hospital with the potential for further expansion across Ghana.

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Appendices

Appendix A: Web Application Proposal for the Greater Accra Regional Hospital

Greater Accra
Regional Hospital
RIDGE

WPI

WEB APPLICATION PROPOSAL

For the Greater Accra Regional Hospital

Abstract

This proposal is intended to guide the development of a web application to improve the efficacy and efficiency of broken medical device reporting for the Greater Accra Regional Hospital.

Ana Grandgeorge and Elisabeth Lynn

Executive Summary

This proposal is intended to guide the creation of a web application to improve the efficiency and efficacy of medical device reporting in the Greater Accra Regional Hospital. It compiles the research, product specifications, and client needs, and describes the implementation and concept design of this application in detail.

The hospital's current system for reporting broken medical devices relies on engineers to check in with each of the 50+ hospital units who then report if a device is broken. This process is time consuming and lacks a reliable system of communication between the nurses and the engineering department after a device has been taken to be fixed. The process was observed through shadowing of the engineering department. Product specifications were made based on these observations and background research. It was determined that the new system would need to improve communication and be user friendly, secure, time efficient, accurate, accessible, and affordable. Client needs were then divided into three categories: engineering department, nursing, and management. The engineering department's primary needs are improving communication and efficiency. The nurses' needs are improving communication, creating a way for nurses to receive updates on devices, and having a better way to request new equipment. The management needs to be able to see long-term data on commonly broken devices to make decisions on future investments.

Because of the complexity of the system, a phased approach for implementation is suggested. The features of the system were divided into necessary and non-necessary features, with the latter being less important, but still beneficial to the users. Additionally, the necessary conditions to adhere to the requirements of the Ghana Health Service and the Greater Accra Regional Hospital were considered.

The general concept is described in detail, starting with the login page, then splitting into the different views for the engineering department, nurses, and management. The engineering department has a homepage, a page for all work order requests, and individual pages for each work order. Special capabilities for the head of the engineering department are also detailed. The nurses' view has a homepage, a page to submit work order requests, a submission confirmation page, and a progress updates page. Additional pages with the non-necessary features of requesting equipment and messaging the engineers are also described. The management view has a homepage, a page with all work order requests like the engineers, and a page to see long-term trends in the data. Additional features that are not specific to a certain page are also listed.

This design should be validated through an iterative process in collaboration with the head nurses of a designated unit before being implemented throughout the hospital. It this is successfully implemented at the Greater Accra Regional Hospital and proven to be beneficial, it has the potential to be implemented elsewhere in Ghana. The flexibility of the program would allow it to be modified as necessary for other hospitals or healthcare centers. This application can be designed to suit the needs of the users through continuous input and collaboration.

Introduction

Intentions of Use

This proposal is meant to improve the system for medical device reporting at the Greater Accra Regional Hospital, formerly known as Ridge Hospital. This document was created following the research on medical reporting systems completed at the hospital from January 2023 to March 2023. This research was completed with the goal of understanding the current device reporting system and its key players' concerns, and needs. The belief that the most successful products arise from communication with client needs was the main force that drove the ethnographic research approach. This document is meant to present research findings and a cohesive proposal of the ideal medical device reporting system suited to the hospital. The intention is that information presented in this proposal will guide an information technology/computer science team in the future and provide all necessary information to implement a successful medical device reporting system within the hospital. We hope that with this proposal, the medical device reporting system created can not only have the necessary features for efficient reporting but also have the ability to adapt to future needs and open to continuous improvements.

Overall Concept

The overall concept is a web application that improves ease of communication between the clinical engineering department, the head nurses of each department, and hospital management. The application will allow the head nurse of each department to report any broken medical equipment to the engineering department, the engineering department to respond with progress updates on the reported device, and the management to track data that will guide the hospital in worthwhile future investments.

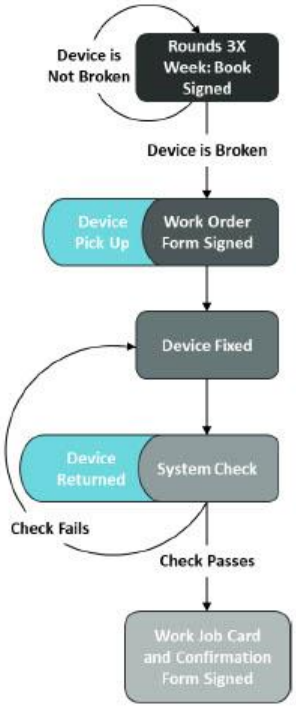
General Information

Hospital Setup

The Greater Accra Regional Hospital consists of two buildings: the original building where the engineering department lies, and the new building connected to the old with a skywalk. The engineering department is responsible for one level in the old building and five levels (0 through 4) in the new building. Within these levels there are over 50 units that the engineering department is responsible for checking in on during rounds.

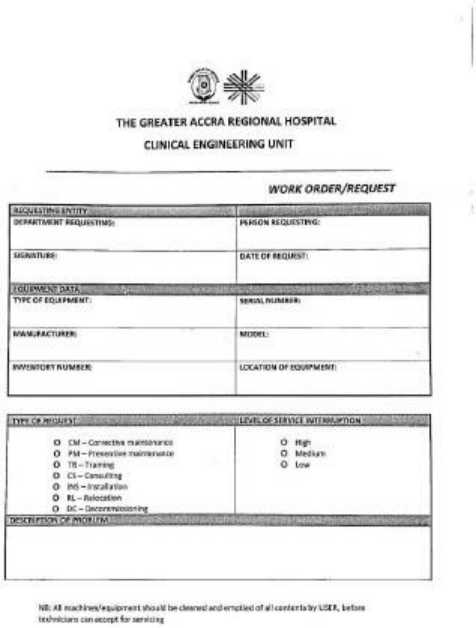
Current System

At the Greater Accra Regional Hospital, broken biomedical devices are reported through a system of paperwork and personal communication. An overview of the entire system is shown below.



Three times a week, rounds are completed to check in with each department and determine if there are issues with any devices. The engineering department has a record book for each level of the Greater Accra Regional Hospital. The team will divide into groups assigned to cover one or two levels for the day. The group will go to the head nurse of each department on that level to ask if there is any broken equipment. Regardless of whether there is an issue or not, each head nurse must sign the book confirming that the round was completed. If there is an issue, the engineers will do a preliminary scan on the device with some basic troubleshooting, complete the rounds in the remaining departments, then return with a Work Order/Request form. The device is not taken from the unit to the engineering workshop until the Work Order/Request form is completed.

This form is one of the three forms that are filled out by the clinical engineering department: the Work Order/Request form, the Work Report/Job Card, and the Certification of Work. The Work Order form is the form that officially opens a complaint with the clinical engineering department. This form takes note of the problem the user is facing, as well as information on the equipment, the requesting entity, request type, and level of service interruption, as seen below. It requires a signature from the person requesting the work. After these forms are completed and signed, they are photocopied and saved in an online record.



THE GREATER ACCRA REGIONAL HOSPITAL

CLINICAL ENGINEERING UNIT

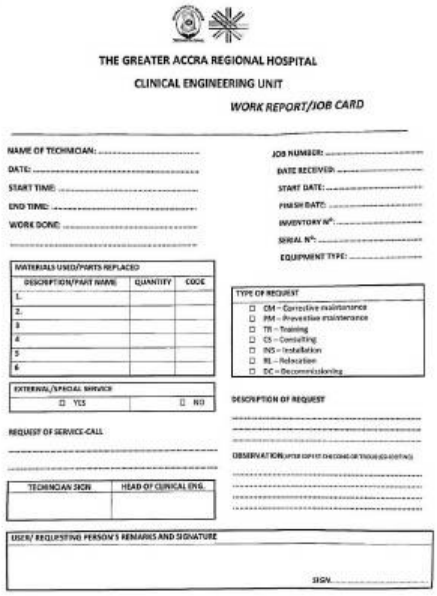
WORK ORDER/REQUEST

REQUESTING ENTITY	
DEPARTMENT REQUESTING:	PERSON REQUESTING:
SIGNATURE:	DATE OF REQUEST:
EQUIPMENT DATA	
TYPE OF EQUIPMENT:	SERIAL NUMBER:
MANUFACTURER:	MODEL:
INVENTORY NUMBER:	LOCATION OF EQUIPMENT:

TYPE OF REQUEST	LEVEL OF SERVICE INTERRUPTION
O CM – Corrective maintenance O PM – Preventive maintenance O TR – Training O CS – Consulting O INS – Installation O RL – Relocation O DC – Decommissioning	O High O Medium O Low
DESCRIPTION OF PROBLEM	

NB: All machines/equipment should be cleaned and emptied of all contents by USER, before technicians can accept for servicing

The Work Report/Job Card form serves as a record of the issue and the maintenance performed on the device and notes any replacement parts used. It requires a signature from both the technician who worked on the device and the head of the clinical engineering department.



THE GREATER ACCRA REGIONAL HOSPITAL

CLINICAL ENGINEERING UNIT

WORK REPORT/JOB CARD

NAME OF TECHNICIAN: .....

DATE: .....

START TIME: .....

END TIME: .....

WORK DONE: .....

.....

JOB NUMBER: .....

DATE RECEIVED: .....

START DATE: .....

FINISH DATE: .....

INVENTORY N°: .....

SERIAL N°: .....

EQUIPMENT TYPE: .....

MATERIALS USED/PARTS REPLACED

DESCRIPTION/PART NAME	QUANTITY	CODE
1.		
2.		
3		
4		
5		
6		

TYPE OF REQUEST

- ☐ CM – Corrective maintenance
- ☐ PM – Preventive maintenance
- ☐ TR – Training
- ☐ CS – Consulting
- ☐ INS – Installation
- ☐ RL – Relocation
- ☐ DC – Decommissioning

EXTERNAL/SPECIAL SERVICE

☐ YES ☐ NO

DESCRIPTION OF REQUEST

.....

.....

.....

REQUEST OF SERVICE-CALL

.....

.....

OBSERVATION(AFTER COPY OF THE CODE OF THOSE EQUIPMENT)

.....

.....

.....

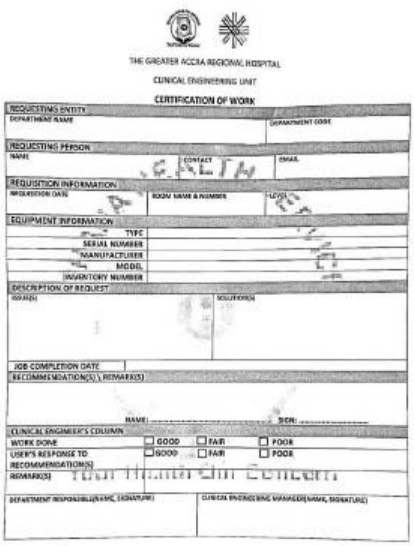
.....

TECHNICIAN SIGN	HEAD OF CLINICAL ENG.

USER/ REQUESTING PERSON'S REMARKS AND SIGNATURE

SIGN.....

Finally, the Certification of Work form describes the issues, solutions, and recommendations, as well as the equipment information and request information. It requires a signature from both the head of the requesting department, and the clinical engineering manager.



THE GREATER ACCRA REGIONAL HOSPITAL

CLINICAL ENGINEERING UNIT

CERTIFICATION OF WORK

REQUESTING ENTITY

DEPARTMENT NAME | DEPARTMENT CODE

REQUESTING PERSON

NAME | CONTACT | EMAIL

REQUISITION INFORMATION

REQUISITION DATE | ROOM NAME & NUMBER | LEVEL

EQUIPMENT INFORMATION

TYPE

SERIAL NUMBER

MANUFACTURER

MODEL

INVENTORY NUMBER

DESCRIPTION OF REQUEST

ISSUE(S) | SOLUTION(S)

JOB COMPLETION DATE

RECOMMENDATION(S) \ REMARK(S)

NAME: _____ SIGN: _____

CLINICAL ENGINEER'S COLUMN

WORK DONE ☐ GOOD ☐ FAIR ☐ POOR

USER'S RESPONSE TO RECOMMENDATION(S) ☐ GOOD ☐ FAIR ☐ POOR

REMARK(S)

DEPARTMENT RESPONSIBLE(NAME, SIGNATURE) | CLINICAL ENGINEERING MANAGER(NAME, SIGNATURE)

According to the Ghana Health Service, it is the responsibility of the hospital staff to report any issues or malfunctioning of equipment. However, the current system relies on the clinical engineering department seeking out any issues.

Research Approach

The goal of the research project was to better understand the innerworkings of how broken medical devices go through the process of being fixed to provide recommendations of an improved system. This was achieved by doing preliminary research on medical device reporting policies provided by Ghana Health Services, understand the current system of reporting through shadowing the engineering department, and speaking with various stakeholders at the hospital. This was done to identify common issues and areas for improvement within the system.

Product Specifications

Based on the research conducted, the following product specifications were developed to guide the design of a new system.

1. **Proper Communication**: The system should improve communication between the head nurses and the engineering department.

2. **User Friendly**: The system needs to be simple to navigate and easy for all users to learn. Otherwise, no one will have a desire to pick up the new system, causing more complaints than the current system.
3. **Security**: The system should be secure in the sense that only those who need to use the system have access to it. The data collected on the devices and their issues should be safely stored and given to the engineering department head and hospital management.
4. **Time Efficiency**: The system must achieve time efficiency in multiple aspects. Decreases should be seen in the time between each device being broken and fully operating in the unit again, the time for rounds to occur, and the time that the engineers are receiving calls about issues. This specification allows the engineers to have more time to focus on getting the device functioning as soon as possible
5. **Accuracy**: The system should allow for data on devices and issues to be accurate.
6. **Accessibility**: The application and all components of the system must be easy to find.
7. **Affordability**: The system must be affordable for the hospital. The system should be designed to be aware of any costs related to service and maintenance.

Client Needs

The system for medical device reporting is held together by the relationship between three categories of clients: the clinical engineers, the head nurses of each unit, and the management of the hospital. Based on our research, the following needs were discovered.

Engineering Department

Currently, after a device has been reported as broken, there is no consistent method of communication between the nurses and the clinical engineering department for updates on the device. There is a need for a system that allows the nurses to receive progress updates from the engineers to increase communication between the two departments. Another major concern to be addressed is efficiency. The current system requires a significant amount of time for the engineers to complete rounds, which is time that could be used for more relevant work. An ideal system would eliminate the time it takes to complete rounds altogether, as well as minimizing the time it takes for a broken device to been seen by the engineering department, as the reports can come in real time.

Secondary needs that the system would have to address include minimizing the number of complaints the head of the engineering department receives via phone call and allowing the reports to be sorted by importance.

Nursing

As previously stated, the lack of communication between the nurses and clinical engineering department is an area for improvement. It is common for nurses to ask for updates on reported devices during rounds, but because the engineers' floor for rounds does not necessarily correspond to the devices they work on, the nurses questions often go unanswered. Additionally, nurses will often request new equipment either on rounds or via phone call to the head of the engineering department, so incorporating that functionality into a new system would be beneficial both to the nurses and the engineers.

Management

The medical reporting process produces a lot of data that could be valuable to management. This data could be better utilized to identify common issues with device categories, companies, and models, that could guide the hospital's purchases. Data around the cause of device malfunctions can result in new training to guide users.

Implementation

Overall Implementation Phase

In order to implement the system effectively, it is recommended that the system is developed to adhere to the needs and wants of the clients as listed in this document. Once the application is developed the system should be first implemented in one or two units in order to gain feedback and improve upon the system before integrating it into all units.

Considering the time that it may take for the application to be developed, it may be best to add features to the system according to their importance. These features can be divided into necessary and non-necessary features.

Necessary Features

The following features have been deemed necessary to the system's success.

- Login
- Account capabilities vary based on the following user types: nurse, engineer, and management
- Work Order/ Request Form
- Work Request/Job Card
- Confirmation of Work Form
- Progress updates
- Phone and computer application

Non-necessary Features

The following features have been deemed non-necessary to the system as a whole, but very beneficial to the users involved. These features are ranked at a lower priority than those deemed necessary.

- Surgery Calendar for engineers who need to sit in on operations

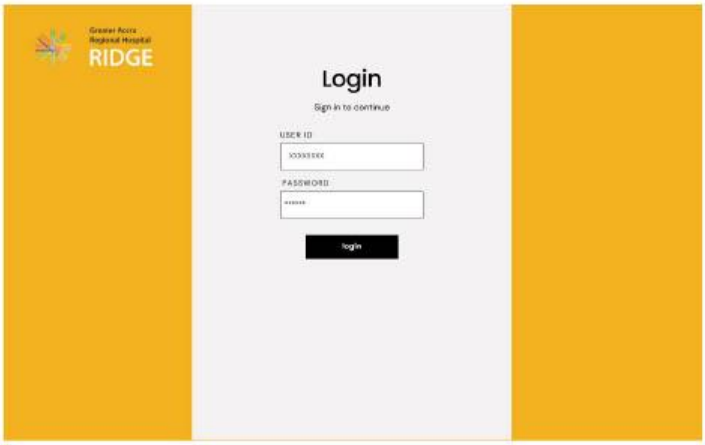
- Database of Manuals for devices
- Way to request new equipment
- Training videos
- Ability for head engineer to assign jobs
- Troubleshooting tips and flowcharts
- Chat

Necessary Considerations

Beyond the features necessary to meet the client needs, conditions need to be met to uphold the standards set by the Ghana Health Service and the Greater Accra Regional Hospital. The primary requirement is the logging of user information for any request or updates submitted. Anything submitted should record the user ID of the person, as well as the date and time. This is in place of a signature that is required on physical documents. The user IDs should be the same as the ID numbers used by the hospital management system and will be inputted into the login page at the launch of the application.

Login Page

This is the first page that all users see. They can log into their accounts using the same user ID they are assigned to for the hospital. Depending on the user's ID (nurse, engineer, or management), they see a different interface once they log in.



Design: Engineering View

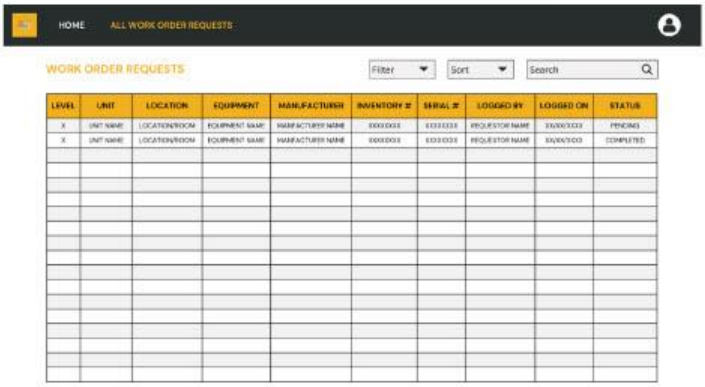
Homepage

This is the homepage for the engineering department. This page consists of four sections: new requests, pending requests, request summary, and calendar of events. These sections allow the engineers to have a clear understanding of what requests still need to be completed and what new issues have occurred. A new request is moved to a pending request once it is seen and electronically signed by the engineer to confirm that the work order is in place. The request summary shows how

many devices are in each stage of the repair process. This graph feature is clickable, taking the user to the work order requests page, with a filter based on the status they clicked on. The calendar feature tracks when surgeries occur that need an engineer to assist.

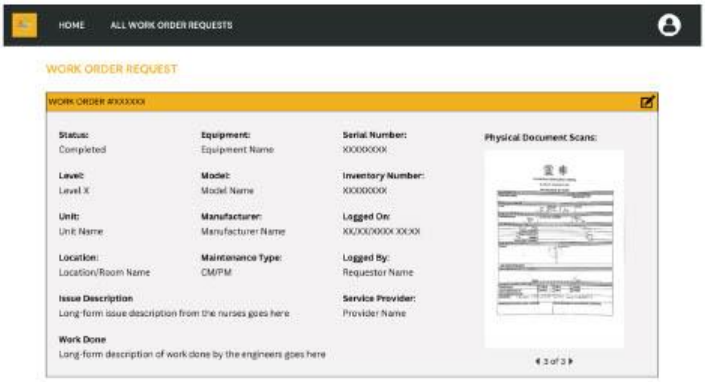
All Work Order Requests

All the work order requests that nurses have reported go to the "All Work Order Requests" page on the application. A sample of what the display looks like is shown below. Requests have the option of being sorted by date of report, date of completion, or level of service interruption. The default display shows the most recent reports. The reports can also be filtered to show specific floors, units, levels of service interruption, and statuses. Engineers can select multiple filters at once. There is also a search feature. Each request is clickable, and links to a page with the full details of the request. Additionally, the engineers can designate unit names if the hospital expands or goes through changes. These changes are also reflected in the nurse's interface.



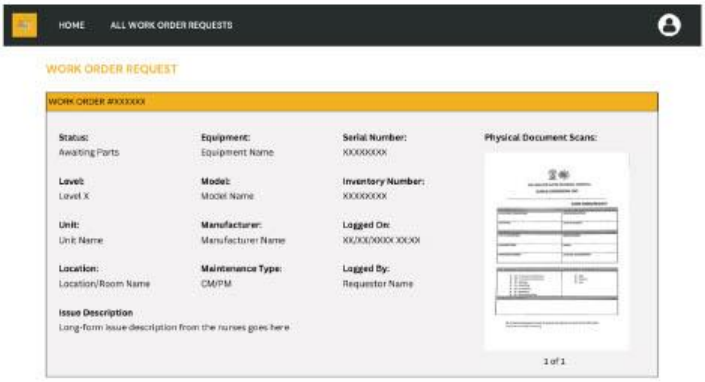
Work Order Request: Completed

A sample of a completed work order report is shown below. This report has all the information from the initial request made by the nurse, as well as a section for work done by the engineers, the physical document scans, and the service provider information.



Work Order Request: Pending

Alternatively, if a report from a nurse has just been submitted or is in progress, the page shows up as seen below. This page has only the initial data inputted by the nurses, and a work order form or job card if applicable.



Special Capabilities: Head of Engineering

The head of the engineering department has the capabilities of both the clinical engineers and the management. The homepage is identical to the clinical engineering homepage, but the management view home page is also included in a separate summary tab, as well as a tab for the long-term data that the management can access.

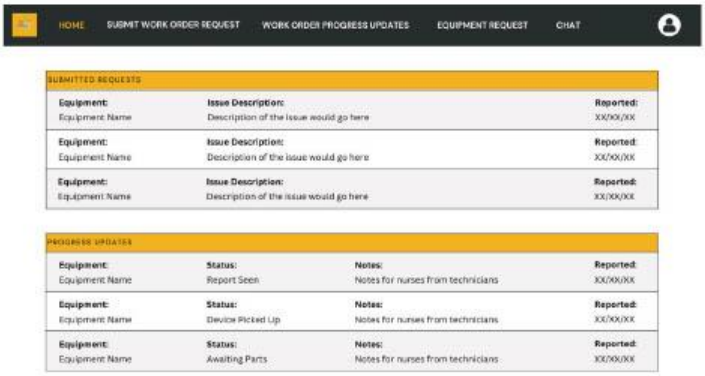
Another capability to be explored is the ability to assign jobs to people as requests come in. This allows the head of the engineering department to better delegate tasks and increase accountability.

The head of engineering is also able to edit the drop-down sections of the work order request form to be able to add/edit the units of the hospital. Hospitals are always changing and expanding so this is a necessary capability for the department head to have.

Design: Nurses View

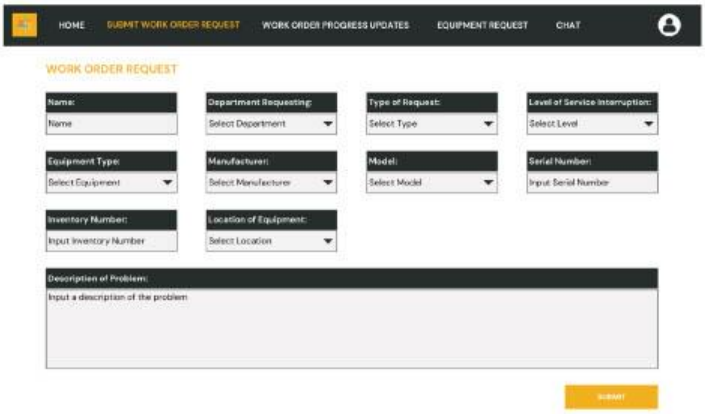
Homepage

This is the homepage for the head nurses of each unit. The requests show up for the specific unit that the nurse works in, depending on the login information. The progress updates section of this interface shows any devices that have an updated status from the last time that the nurse has logged in. The submitted requests section contains all requests that have been submitted in order of the date they were reported.



Submit Work Order Request

The submit work order request section allows the head nurse to report an issue to the engineering department. This form contains all necessary information for the Work Order/Request form. Any changes made by the engineers in terms of departments/units are reflected here in the nurse's request form as well.

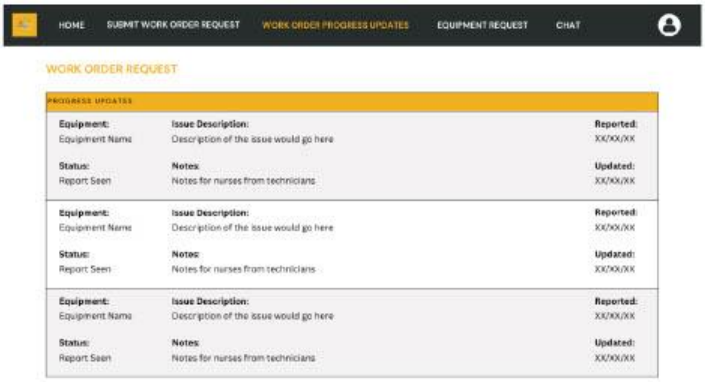


Work Order Request Submission

Once the work order request is submitted, the nurse is led to this page, confirming that the request has been received. This page also links back to submit another request, if necessary.

Progress Updates

The work order progress updates provide detailed information on what stage of repair the device is currently under. This allows the nurses to have more communication with the engineering department while their device is being received.



Equipment Request

The equipment request page is meant for nurses to submit a request for any new equipment they may need that the engineering department may have or be able to order. This form does not currently exist, as requests are usually made over the phone to the head of the engineering department or during rounds.

Chat

The chat page is meant for nurses to further communicate with the engineering department. It also functions as live support for any troubleshooting issues.

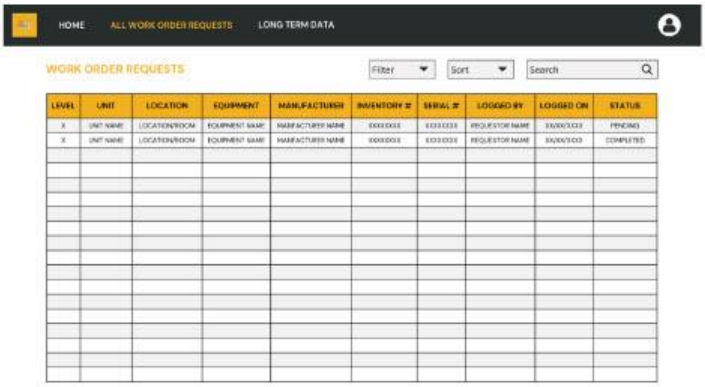
Design: Management View

Homepage

The homepage for the managers serves as an overview of the complaints/requests to the engineering department. It displays the number of complaints in the last several months, the oldest pending requests to see if any have been going on for an extended period of time, and a chart with the statuses of the requests in progress.

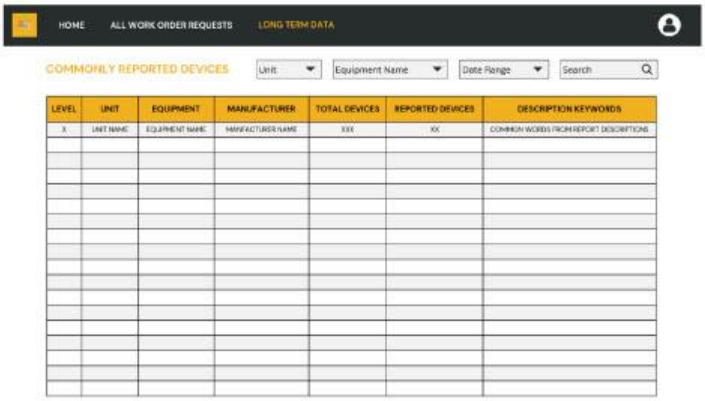
All Work Order Requests

This page is identical to the engineer's page and displays all the work order requests for the management to see.



All Data

This page displays the devices that are most commonly reported as broken. For each model of equipment, it displays the total number of such devices in the hospital, and how many were reported in the date range that they select. It also compiles frequently used words from reports to see if there are any commonalities with the reports.



Additional Features

Managers are able to see the interface of the engineers and nurses as well. This is available through the profile section. Managers (and the head of the engineering department) are also able to designate new users as engineers, nurses, or managers, and make changes to the existing userbase. This is also accessible through the profile section.

Verification/ Validation

We recommend that once the system is created, it is first integrated into a single unit to undergo testing. As with the creation of the system, collaboration with the clients is crucial to the success of the system. At this stage, once the system has been designed, the client focus would shift from the nurses to the engineers. Any head nurses that are willing to participate would provide feedback on the ease of use of the system. With this feedback in mind, the system would be modified as needed then retested. This process would continue until the nurses are satisfied with the interface. The system would then be implemented throughout the hospital in phases to ensure that there are no further issues.

Conclusion

Future Recommendations

If this application is proven to be successful and beneficial at the Greater Accra Regional Hospital, it could be implemented in other hospitals around the region. This application should have the ability to be modified as needed to suit the needs of the users. Should more needs come up, the application would serve as a platform to address them. Because of this flexibility, it could be adapted to serve hospitals or health care centers beyond just the Greater Accra Regional Hospital. Should the application expand its reach, an additional feature for managers to customize the interfaces that nurses and engineers see could also be beneficial to better suit their specific needs.

Successful implementation of this application hinges on the continuous input from the clinical engineering team. With this type of collaboration, the project can be successfully designed to suit their needs. We hope that WPI continues its relationship with the Greater Accra Regional Hospital and that together, we can create something that provides value for the hospital.