ADDIS ABABA UNIVERSITY

SCHOOL OF INFORMATION SCIENCE

And

School of Public Health

M.Scin Health Informatics Program

Web- Based Medical Equipment Information Management System, The Case of Dire Dawa Administration Health Bureau

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A Project Submitted to the School of Information Science and Public Health of Addis Ababa University in Partial Fulfillment of the Requirement for Degree of Master of Science in Health Informatics

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ACKNOWLEDGEMENT

I would like to thank Addis Ababa University school of Information Science and school of Public Health for providing me this opportunity. My special heartfelt thanks go to my advisers Ato Ermias Abebe and Dr. Negusse Deyessa for their patience, encouragement, stimulating advices, and constructive suggestions, who helped me to pass through all the challenges and complete my project. A special thanks to Mesert Ayaneo for her kind and precious help on the administrative part.

I would like to pass my special thanks to my friends Free Amde and Mahdi Abdella for the information and supports they provide me, all the time I need, and all my staffs who support me and initiate me to join this study program. My special appreciations go to the staff of the Biomedical Department specially Ato Anteneh Berhanu for providing me all the necessary information.

Last but not least, I would like to pass my sincere gratitude to my beloved family, specially my mother who provides me special support and her limitless love.

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Acronyms

AMT	Active Management Technology
BPR	Business Process Reengineering
CASE	Computer Aided System Engineering
CED	Clinical Engineering Department
CM	Corrective Maintenance
CRCP	Curative and Rehabilitative Core Process
DFD	Data Flow Diagram
DPCP	Disease Prevention Core Process
EFY	Ethiopian Fiscal Year
EMIS	Equipment Management Information System
FDA	Food and Drug Administration
FMoH	Federal Ministry of Health
GHTF	Global Harmonization Task Force
HR	Human Resource
HSDP	Health Sector Development Program
HTML	Hyper Text Markup Language
ISD	Information System Development
ITEA	Information Technology for European Advancement
KEMS	KALMAN Equipment Management System
MEIMS	Medical Equipment Information Management System
MEMS	Medical Equipment Management System
MySQL	My Structured Query Language
OO	Object Oriented

PFSA	Pharmaceutical Fund and Supply Agency
PHS	Peripheral Health Care
POC	Point Of Care
RHB	Regional Health Organization
SDLC	System Development Life Cycle
PM	Preventive Maintenance
UC	Use Case
UIP	User Interface Prototype
UI	User Interface
UML	Unified Modeling Language
WHO	World Health Organization

Abstract

Background: In delivering the health care service, health professionals use different kinds of medical equipment to provide quality health care service. Medical equipment is any instrument, apparatus, machine, appliance, implant, in vitro reagent or calibrator, software, material or other similar or related article which does not achieve its primary intended action in or on the human body by pharmacological, immunological or metabolic means. Medical equipment information management system is used to automate the documentation of all activities relating to medical equipment.

Objective: The objective of this project is to design web- based information system for medical equipment management taking the Dire Dawa administration health bureau as a case.

Methodology: This project is conducted in Dire Dawa administration health bureau for the biomedical case team. This project follows the design science methodology. Object Oriented analysis and design methodology is used for requirement analysis and design. Purposive sampling was used to find the study area. In depth interview and document review were done to analyze the existing situation. UML techniques were used to model the analysis and design of the new proposed system. The investigator uses HTML, PHP and MySQL to design system prototype.

Discussion Of Result: The use case diagram identifies all the process and system boundary of the proposed system. Eleven processes were identified with their corresponding actors. Fourteen objects of the system were identified and modeled using the class diagram. The flow and sequence of the processes were presented using the sequence diagrams. User prototype was modeled for the system usability testing.

Conclusion: This project does not show the final product of the system, rather provides system prototype for further continuous evaluation and development along with the user feedback input. In addition to the system prototype, the project identifies the points need to be improved and the areas need further investigation in the existing system.

Chapter One

1. Introduction

1.1. Background

Dire Dawa administrative city is found in the eastern part of Ethiopia. It is 517 km away from the capital city Addis Ababa. The population of Dire Dawa is around 400,000.

The Dire Dawa administration health bureau has four core processes and two supportive processes. The core processes are Disease Prevention, Curative and Rehabilitative, Regulatory, and Plan and program core processes. The supportive processes are Human Resource and Finance.

According to the definition by the Global Harmonization Task Force (GHTF),

> "medical device is any instrument, apparatus, implement, machine, appliance, implant, in vitro reagent or calibrator, software, material or other similar or related article which does not achieve its primary intended action in or on the human body by pharmacological, immunological or metabolic means, but which may be assisted in its intended function by such means"(1).

Medical equipment is part of medical device which needs calibrating, maintaining, repairing, and decommissioning. It excludes implantable, disposable or single use medical devices(2).

Health facilities provide a variety of health care services depending on the level of the facility. In delivering the health care service, health professionals use different kinds of medical equipment to provide quality health care service. "Medical equipment is crucial in the prevention, diagnosis and treatment of illness and disease, as well as patient rehabilitation"(3).

In health facilities wide variety of medical devices are being used, which may range from simple tools used during medical examination like a thermometer, or high complex lifesaving medical devices like heart valves and coronary stents.

According to the standard set by the Federal Ministry of Health (FMoH) of Ethiopia, primary hospitals, health centers and health posts should be equipped with 180, 150, and 120 different types of medical equipment respectively at a minimum(4).

The Biomedical department or clinical engineering department of health bureau is responsible for including and excluding medical equipment in the health technology management program for tests, repairs and maintenance. Appropriate management of medical equipment ensures safe and effective health service provision (5).

Medical equipment information management system (MEIMS) is used to automate the documentation of all activities relating to medical equipment and provide report and notification message for planned maintenance(6).

As WHO medical device technical series in 2011 stipulate, MEIMS incorporates equipment and spare parts inventory modules, preventive and corrective maintenance module, and contracts management module(3). The analyzed records of these modules can be used for the technology management, quality assurance, work order control and budgeting of medical equipment.

As a result of a critical examination of the nature, magnitude and root causes of the prevailing health problems of the country, the transitional government of Ethiopia had issued its health policy in September, 1993[1]. One policy priority is that the

> "provision of essential medicines, medical supply and equipment shall be strengthened, and among the strategies that had been issued to assure the availability of drugs, supplies and equipment were the listing of essential and standard drugs and equipment, and updating such lists, encouraging national production capability of drugs and equipment, and developing maintenance and repairing facilities for equipment" (7).

Therefore, a medical equipment information management system is an essential component in implementing the government health strategy.

[1]Note: Years indicated in this project report are in Gregorian calendar except where it is indicated otherwise.

1.2. Statement of the Problem

Medical devices can cause a serious problem for users and patients, if they are not well managed during health care service provision. Food and Drug Administration (FDA) agency of the United States in 2006 reported 116,086 device related injuries, 2,830 deaths and 96,485 malfunctions of device (8). This shows, that the poor use or mismanagement of medical equipment has an effect on the health care service quality. Therefore, it is important to have documentation and reporting system to identify and solve medical equipment related problems in a given health care organization.

In a study done by the department of Mechanical Engineering, Laval University in Canada, it is found that 32.2% medical equipment repair calls made due to equipment management issues and 13.7% is related to inadequate preventive maintenance for the equipment, setup and uncategorized calls (9).

From this study, we can understand that the lack of medical equipment management can cause a failure of the equipment which results in repeated repair calls and increase in the cost of maintenance. On the other hand, if medical equipment information management system is put in place, it can help to implement a planned preventive maintenance for the equipment and reduces cost by providing adequate and proper information about the equipment being used.

The research done over maintenance management of medical equipment in major hospitals of Kenya reported that, the responsible public organization on maintenance does not have proper management of medical equipment (10). The problem identified in Kenya is also experienced by our country.

A research done relation to this, in Ethiopia shows that the lack of equipment management is the source for equipment failure. Further, newly acquired equipment lie idle. The essential ingredients missing in the majority of research institutes and universities in Ethiopia are the organizational structure and functioning system that create enabling situations for scientific equipment and technology management through their lifecycle. It is recommended to create an enabling scientific

equipment management system for these institutes. These problems of equipment management are also shared by the health institutes found in the country (11).

The cost of medical devices globally as well as nationally is very high. In 2006 global market figure of medical device was expected to exceed US$260 billion(12). Nationally, from the Health Sector Development Program (HSDP) quarterly health bulletin report in April 2014, the Pharmaceutical Fund and Supply Agency (PFSA) has distributed pharmaceuticals and medical equipment worth ETB 8.19 billion in 2005EFY (13).

In Ethiopia, the lack of proper management of medical equipment has limited the capacity of health institutions to deliver adequate health care. It is estimated that only about 61% of medical equipment found in Ethiopian public hospitals and other health facilities are functional at any one time (14).

As the information gained from the head of the biomedical case team of Dire Dawa city Administration health bureau indicates, there are problems associated with the management and information availability on medical equipment. As health care delivery continues to expand and improve in the region and an increasing number of sophisticated medical equipment is introduced, a system capable of supporting and managing the medical technology must be put in place.

The intention of this project is therefore, to develop medical equipment information management system that may help the region to be more efficient and effective in managing the maintenance and use of medical equipment so as to provide a reliable and quality health care service.

1.3. Objective of the project

1.3.1. General Objective

The general objective of this project is to design a web- based information system for medical equipment management, taking the Dire Dawa administration health bureau as a case.

1.3.2. Specific Objective

The specific objectives are to

- Identify user and system requirements of medical equipment information management system for Dire Dawa administration health bureau;
- Analyze the system requirements identified;
- Design system model of the medical equipment information management system;
- Design general (high level) system architecture of the medical equipment information management system;
- Test user interface prototype model of the system;
- Develop a prototype of the medical equipment management information system to demonstrate its potentials;

1.4. Significance of the Project

The new medical equipment information management system will hopefully provide different functionalities for different individuals.

Users and health professionals

- The system makes their work easier, effective, and efficient.
- It helps them in tracing and controlling the performance of a specific medical equipment.
- It helps the health professionals in providing quality health care service.

Patient

- Make them to conserve save, accurate and quality health care service.
- Reduce the risk of medical equipment accident on the patients.

Administrative Health Bureau

- It helps to have the general future of medical equipment inventory information about the region.
- It helps in the procurement planning of medical equipment.
- It helps to identify the gaps of medical equipment management and set solution.
- Help in resource allocation for medical equipment management and controlling activities.
- Provide system prototype ready for implementation

Other student / Researcher

- Provides complete information of medical equipment for study and research purpose.
- It can be used as starting point for other related projects.

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1.5. Scope of the project

This project is limited to the design of a web based medical equipment information management system and a system prototype thereafter. The project does not present a complete outstanding system rather it provides a first blueprint of the initial system development iteration process output. It also includes the initial user interface prototype testing. This project is implemented for Dire Dawa Administrative Health Bureau biomedical case team and three health facilities, Dilchora hospital, Sabiyan primary hospital, and Gendkore health center as a pilot. The medical equipment included in the management information system are those instruments, apparatus, machine, calibrator, materials and vitro reagent used for prevention, diagnosis, treatment and rehabilitation service provision for a patent, excluding implantable, disposable or single use medical equipment. The project executed in the duration of Jan, 2015 up to May, 2015. The project uses an Object Oriented methodology as modeling method and the iterative process modeling as a process of analyzing and designing the system. The technique used in this system analysis and design are UML modeling techniques. To present the UML models and the user interfaces prototype of the system Visio and White Star CASE tools are used. PHP, HTML programming language and MySQL database management system are used to implement the system software prototype. The system architectural design is presented using three tire client server system architecture. The hardware requirement and network design are not included in this project.

Chapter Two

2. Literature Review

2.1. Medical Equipment and Medical Equipment Information Management System

2.1.1. Medical equipment

To complete the diagnoses and treatment for patient with care, the medical environment is highly dependent on various types of medical equipment.

"Medical equipment is any instrument, apparatus, implement, machine, appliance, implant, in vitro reagent or calibrator, software, material or other similar or related article which does not achieve its primary intended action in or on the human body by pharmacological, immunological or metabolic means, but which may be assisted in its intended function by such means"(15). It excludes implantable, disposable or single use medical devices (16).

Medical equipment must be kept in good condition to prevent from injuries occurred in patient as well as in users. Moreover, to compete with the dynamic environment and complex health care system, health institutions should take the appropriate cost controls in response to that situation(17).

The biomedical engineering unit in health institution is responsible for the patient and clinical staff safety in using medical devices. In addition to the cost control in related operational activities of a medical device, such as purchase, contract, repair, and maintenance, is another important job for this unit. (18)

2.1.2. Medical Equipment Information Management System

MEIMS is a system that deals with the management of medical equipment information, for the purpose of supporting health care technology management in making the equipment used safely and effectively. MEIMS incorporates equipment and spare part inventory modules, maintenance module, and contracts management module (3).

Each module has its own information table. Equipment inventory module contains manufacturer information, location and all fields necessary for effective health technology management are included. The module help to record equipment

information using the equipment code given to a specific device. The spare part inventory module tracks the spare part related to the equipment. It helps to manage the stock level and report on the consumption of reused parts. The two main parts of maintenance module are the planned preventive maintenance, which helps the user in calculating when a piece of equipment will require maintenance. The second part is the corrective maintenance, which helps in generating a work order for the specific equipment maintenance request and capture all information on maintenance. The contract management module is used to track all externally provided maintenance services (3).

MEIMS provides an advantage of automated preventive triggers, easy auditing process, reporting, centralize database, real time information, and communication among responsible staffs. It enables to track the status of maintenance work on items and the associated costs of that work in one system. MEIMS can be designed in the way it suits with the interested institute. This system commonly has a different nomenclature in different places like, Enterprise Asset Management software, Maintenance Management software, Work Order Software, Work Order Management Software, Facility maintenance software and so on (19).

2.1.3. Information System Management

The information system is a transformation of data consists of basic fact into an output that is valuable to users. It is the collection of technical and management resources that provide the storage, computing distribution, and communication for the information required by all or any part of an enterprise. Information system management is the application of information technology to support the major function and activities of the institution. It uses to solve business problems and the management of technology.

2.2. System Development Methods, Tools, and Techniques

2.2.1. Information System Development

Information system development(ISD) is steps taken to change object system in a specific environment using a different group of tools and an organized collection of techniques. Which is in general called method. ISD is expected to include manual and computerized parts of an object system. (20). In addition to the techniques and tools, a developer can use the different process model and modeling methods in the development process of an information system.

2.2.2. Modeling Method

Modeling is a way of depicting the existing business domain in understandable system concept. It also shows the benefits of abstracting complex system to model form. Different system developers can use different modeling methods like, Traditional, structured and Object Oriented modeling methodology.

Structured analysis and design are process centered approach that transform data into useful information. It uses a series of phases, systems development life cycle (SDLC), to plan, analyze, design, and implement (21).

In an object oriented analysis and design, it describes the real world of its objects, the attributes, operations, and relationships. It is the object perspective of the problem domain. In contrast with the structured modeling, object oriented modeling combines data and processes that act on the data into things called objects. Its flexible, efficient, scalable and easy transition to OO programming languages make it popular in an information system development (21).

The Object Oriented approach uses the inheritance principle that increases the advantage of reusability of functions and introduces standardized ways of performing basically similar functions on the data. This principle of OO is contradicts with the principle of design used by the structured approach (22).

2.2.3. Techniques

Technique mean a set of steps and a set of rules which define how a representation of an information system is derived and handled using some conceptual structure and related notation. Object Oriented analysis and design use static and dynamic UML (Unified Modeling Language) techniques to visualize and document an information system. UML models are used to show the analysis and design of an information system in a different modeling diagram like, Use Case, Activity, Class and Sequence diagrams (21).

Data Flow Diagram (DFD) is a technique used to show the business process and the data that pass among them. If focus mainly on the process or activities that are performed(21). From this point it is clear that DFD more goes with structural system analysis and design approach.

CASE is a Computer Aided System Engineering tool which uses to simulate and draw different models for the system to be developed. It visualizes the blueprint of the system for the users and make them evaluate and give feedback easily. This tool is important in helping the developer to identify the gaps of the system as early as possible. It makes life easy for the developer because it is easy to edit it repeatedly. There are different tools available for modeling diagram like, Visio, Ambrello, and White Star (21). In contrast with the other tools, Visio uses to draw the modeling diagrams as well as the user interface prototype, where the only other use for modeling diagram.

2.2.3.1. Use Case Diagram

An accepted way of accomplishing functional requirement of system is the use case analysis. Use case analysis is a case based way of describing the uses of the system with the goal of defining and documenting the system requirement. It is a powerful technique that describes the kind of functionality that a user expects from the system. It does this by defining a number of actors, which model the roles that users can play when interacting with the system, and describing the use case that those actors can participate in.

A use case diagram is a visual summary of several related use cases within a system or subsystem. It shows the system boundary clearly and what is included

in the system. The description of each use case shown within the use case diagram can also be presented in a narrative form. The use case description documents the name of the use case, the actor, description of the use case, a step by step list of the tasks and action required for successful completion, a descriptive course of action, preconditions, post condition, and business rule.

2.2.3.2. Activity Diagram

An activity diagram is a flow chart that shows the actions and events as they occur. They show the order in which the actions take place and identify the outcomes. Activity diagrams are dynamic modeling tools that can help a system analyst understand how objects behave and interact with the system.

2.2.3.3. Class Diagram

A class diagram represents a detailed view of a single use case, shows the class that participate in the use case, and documents the relationship among the classes. It is logical model, which evolves into a physical model and finally become a functioning information system(21). A class diagram is a static model of system, describe the structural relationships that hold between the pieces of data manipulated by the system. They describe how data is parceled out into objects, how those objects are categorized, and what relationship can hold between them. They do not describe the behavior of the system, nor how the data in a system evolve over time.

2.2.3.4. Sequence Diagram

Sequence Diagram is used primarily to show the interactions between objects in the sequential order as those interactions occur. A business level sequence diagram can be used as a requirement document to communicate requirements for a future system implementation. The other primary uses of the diagram are in the transition from requirements expressed as use cases to the next and more formal level of refinement.

2.2.4. Process Model

It is the type of model that shows how a system analysis and design phases proceeding in a system development process. Among different types of process models the one is an iterative life cycle model. "This model does not attempt to start with a full specification of requirements. Instead, development begins by specifying and implementing just part of the software, which can then be reviewed in order to identify further requirements"(23). This process is then repeated, producing a new version of the software for each cycle of the model. In working iteratively, creating a rough product or product piece in one iteration, then review it and improve it in the next iteration and so on until it's finished. It is building and improving the product step by step so that it is possible to track the defect at an early stage. This avoids the downward flow of the defects. In this model it is easy to get the reliable user feedback. In the iterative model less time is spent on documenting and more time is given for designing (23).

A waterfall process model is simple to understand and use. In this process model each phase processed one after another, do not overlap. In this case the system does not tested unless it is developed completely, which reduces the usability of the system (24).

2.2.5. Web based System Development

Internet based system is a series of web pages that provides a user interface, which communicates with one or more levels of data management software and web based database server. A web base system developed and delivered in an internet based framework. This type of system is easily scalable and can run on multiple hardware environments.(21). Developing a web based system, HTML is a language for describing web pages. It stands for Hyper Text Markup Language. HTML codes are used to tell the browser how to display a text, image, and all things need to be displayed on the web page. In a web based system the database of the system needs to be connected with the web page, through which data can be accessed from the database using a web browser. To connect the database to the web, it is necessary to use middleware. A middleware can

interpret client requests in HTML form and translate the requests in HTML form and translate the requests into commands that the database can execute (21). There are different language used to state the middleware process like PHP. PHP is a server side language that allows to embed little programs into the HTML code of a webpage. It gives greater control over what appears in the browser window than HTML alone can provide. PHP-scripts are interpreted by the web server alone, which enable the user to use different type of browser without worrying about language compatibility. The other part in web based system development is the database management. MySQL is the most popular free database engine available today, which supports the standard language of SQL uses to interact with relational database (25).

2.3. Related Works

The medical equipment management information system is used for equipment inventory, a work order system, the preventive maintenance schedules/procedures, outsourcing contract management and all service history records. And also, it is an administrative tool to track equipment, to initiate work orders, to obtain performance indicators, to determine equipment failure trends, to identify training needs, and to produce management reports.

2.3.1. An Equipment Maintenance system

An equipment maintenance system used to maintain equipment master file using magnetic files. It is developed for the industries in Johannesburg. The system contains capital cost data, date of installation, summarized history information like maintenance cost, breakdown frequencies, maintenance work done, and maintenance spare part used for each item. Information stored in this system using punched paper tape or cards. The system provides monthly reports as an output and planned maintenance schedule (26).

2.3.2. KALMAN Equipment Management System (KEMS)

KEMS is designed based on the success of the Vista Asset Management (VAM) solution. It is used by the department of defense agencies in the US. This system is a web base information system that provides real time information on the quantity, specific location, readiness status, and life cycle history of all equipment. The software is provided using an internet browser interface which is paired with share point and SQL. It captures critical information like start and stop time, material consumption, maintenance cost, calibration information and preventive maintenance schedules, and tracks item warranties expiry date (27).

2.3.3. POC-Link

In managing computerized medical equipment, Intel provides Intel vPro technology, including Active Management Technology (AMT). They can manage from a central location by using 3G to connect them to the internet. Advantech company released the POC-W211 point of care terminal which can be integrated with Intel AMT technology. POC-Link software is a remote computer management system based on client/server architecture. It works on POC (Point Of Care) devices with remote monitoring and management capabilities for critical managed items. This software allows biomedical staff to configure, deploy, manage, monitor, diagnose and maintain distributed POC terminals remotely irrespective of their location (28).

2.3.4. Management Information System of Medical Equipment using Mobile Devices

This information system uses a mobile device as central axis of the system. It also uses Qr-codes (2D barcodes) which are decoded to receive on the mobile device critical information about the equipment. Through a web server connectivity the mobile platform uses to generate a service order for the maintenance of biomedical equipment. The main tools used to develop this information system; Java to develop cell phone software due to its compatibility with the device, 2.0

MP integrated camera for capturing of the barcodes of the equipment and GPRS/EDGE connectivity. It also uses Apache web server with PHP and MySQL programming language for the database development.(29).

2.3.5. Medical Equipment Management System (MEMS)

MEMS, designed to manage equipment inventory, work order system, the preventive maintenance schedule, outsourcing contract management and all service history records. The system is developed for in-house Clinical Engineering Department (CED). It is integrated with the health information system of the National Taiwan University Hospital. The web pages of MEMS were designed using Visual studio C#. The web server of CED designed by Front-page and Dream Weaver. To develop the database, they have used Microsoft SQL server and Oracle database (30).

2.3.6. AIMES

Europe is developing a fully integrated approach which reduces manual process, errors, and improve quality with modern electronic business processes for suppliers and hospital on medical equipment management. The project result of AIMES, ITEA2 in Europe shows, the development of logistic management of medical equipment, including inventory control, tracking and dynamic scheduling, medical equipment maintenance, and development of adaptable user interface depending on the specific task. In the project technological advance, there was an end to end problem solving in the hospital based on standard smart phone by the device manufacture's service technician online. Integration between hospital and manufacturers using web service technology was implemented by the project, to make hospital access a device directly and obtain its status. Generally, this project can shows us how an information technology advance the medical equipment management system as whole (31).

2.3.7. PRAXIS

PRAXIS is an in-house developed computerized medical equipment management system. This software is used to enter and store data using relational database. It is networked with different work stations, which allows different user to enter data at the same database. Web-PRAXIS system implemented for the purpose of web-based application and service, centralized database management and support of an application upgrade and data update. WEB-PRAXIS is developed using PHP open source code, which is able to work with Oracle or MySQL (32).

2.3.8. EMIS for Fleet Management

Equipment management Information system (EMIS) is a computer based system that maintains data on motor vehicles owned by Florida state agencies, including car, truck, vans, heavy equipment, and watercraft. EMIS is an old computer application and operates on a mainframe computer system which makes it expensive. The OPPAGA of the state reported that, even though most of the Florida agencies were not satisfied with the performance of equipment EMIS, Three largest agencies were generally satisfied and helps them to control 60% of the motor vehicles within the agencies. The main complaint of the agencies were difficult to use, did not provide needed information, produce outdated reports and staff were reluctant to use EMIS's report believing that the data were inaccurate and unreliable. The EMIS was decided to be redesigned to meet the needs of state agencies (33).

2.3.9. ECRI-AIMS Hospital Equipment Management System

It is web-browser application for managing all aspects of technology based assets in hospitals. In the system, data of the equipment stored centrally in which can be accessed through the hospital intranet. The client uses browser to access central data, there is no software need to be installed on the client side. To develop the central database management system they have used standard Microsoft SQL server database. The system includes six basic system component; equipment, work order, data managers, Administration, customer service, and report. It helps

to manage equipment inventory, work order, service control, spare part, purchasing, and stock control. (34).

2.3.10. PTI/APWA Equipment Management Information System

The public technology Information system group were implementing a computer based information system called PTI/APWA equipment management information system, which helps an equipment manager to understand equipment cost, maintenance characteristics, and equipment performance. The software maintains records for the vehicles utilized by various organizational units. It is all about set of computer programs, worksheets, and forms. The system generates a series of reports monthly and some reports are generated only when requested (35).

2.3.11. Medical Equipment Workflow Management System

Medical equipment, workflow management system was developed to be a helpful tool in asset control and workflow management for the medical device service providers. The system designed in three main modules for its' standard system installation. The three main are equipment inventory, preventive maintenance, and corrective maintenance/repair module. The system contributes benefits of electronic document workflow, work records management, remote access dynamic web application, modular structure, simple software interface, and electronic preventative maintenance checklists. (36)

In general, the above literatures can teach us to what extent an equipment management systems are being implemented. It shows how an equipment can be managed and controlled using different technology in different level, place and time. It also helps us to identify the success and the failure point of a system, What an equipment management system should include, and how a medical equipment management system could be improved over time.

Chapter Three

3. Methodology

3.1. Study Area

The project is implemented in Dire Dawa administration, health bureau for the biomedical case team. Dire Dawa administration, health bureau incorporates two hospitals (one referral hospital and one primary hospital), fifteen health centers and thirty one health posts. The medical case team of the bureau was set up in 2005 during the implementation of BPR at regional level. The team has two biomedical technicians and two biomedical engineers. The aim of the case team was to provide maintenance service for biomedical equipment on all public health facilities in the region. From the paper based inventory made in 2011, it is reported the total medical equipment available in the public health facilities of the region was about 270 in number and 44 in type. And their cost was estimated to be about 14 million Ethiopian Birr. And it's possible to estimate to what extent will increase the number of the medical equipment and its' corresponding cost with the improvement of health care service.

3.2. Study Design

The project is conducted from Jan to May 2015. This project follows the design science methodology, which is the knowledge of using techniques, methods, models, and theory for creating artifacts that satisfy given sets of functional requirement. Object Oriented analysis and design methodology is used for requirement analysis and design. This methodology makes the process of developing system more flexible, easily maintainable and scalable. It also supports the use of an iterative process model which helps to improve the system step by step in a cyclic way until it satisfies the users.

3.3. Study Population

The situational analysis was conducted with all relevant experts of the biomedical equipment case team.

3.4. Sampling Method

The project was done on Dire Dawa Regional Health Bureau, which makes it purposive in finding the area of the project, where the situational analysis was done.

3.5. Data Collection Procedure

To identify business and system requirements, in depth interview was used . All documents like registration used by the biomedical department, formats, reports on equipment inventory and BPR document of the department were reviewed.

3.6. Data Analysis Procedure

UML techniques were used to model the analysis and design of the new proposed system. For the analysis part use case diagram and narrate use cases were used to identify the system boundary and the processes in the system. Activity diagram was also used in the analysis part of the project. Class diagram and sequence diagram were used in the design. The UML techniques are more related with OO analysis and design methodology and the investigator has better knowledge to use it. The tools used to sketch the models and user interface prototype were Visio and White Star UML.

3.7. Date Quality Management

Various efforts were made to assure the analyzed information quality, by referring a different medical equipment standard and guidelines. To achieve optimum system requirement and user satisfaction, users were involved in each verification process of the design.

3.8. Implementation

In the prototype implementation of the project, the investigator used HTML to develop the user interface of client side web page. PHP was used to write the code that connects the web page and the relational database which is created using

MySQL. The investigator used these coding and application because she has more acquaintance write them.

3.9. Operational Definitions

Health technology: The application of organized knowledge and skills in the form of devices, medicines, vaccines, procedures and systems developed to solve a health problem and improve quality of life. It is used interchangeably with healthcare technology.

Medical device: An article, instrument, apparatus or machine that is used in the prevention, diagnosis or treatment of illness or disease, or for detecting, measuring, restoring, correcting or modifying the structure or function of the body for some health purpose. Typically, the purpose of a medical device is not achieved by pharmacological, immunological or metabolic means.

Medical equipment: Medical devices requiring calibration, maintenance, repair, user training, and decommissioning – activities usually managed by clinical engineers. Medical equipment is used for the specific purposes of diagnosis and treatment of disease or rehabilitation following disease or injury; it can be used either alone or in combination with any accessory, consumable, or other piece of medical equipment. Medical equipment excludes implantable, disposable or single-use medical devices(4).

3.10. Ethical Clearance

Ethical clearance to conduct the project was obtained from the school of Public Health Research and Ethical Committee of Addis Ababa University. Permission was obtained from the Dire Dawa Health Bureau in written form and from all departments involved in the project, the consent was obtain verbally. This informed consent from each subject was obtained after clear explanation about the purpose of the project made.

Chapter Four

4. Discussion of Result

4.1. Introduction

The implementer of this project has been using an object oriented modeling methodology and iterative process model to analyze, design and implement the project. To design and develop an information system it is important to have a detailed understanding of the existing system. There are different techniques available for identifying the system requirements. As mentioned in the methodology the system requirement was identified and analyzed using UML modeling technique. The information about the existing system was collected using in depth interview and document review. In this chapter the requirements analysis and design of the system will be presented.

4.2. System Analysis

4.2.1. Current System

The investigator tried to review the current system of the organization, in such way that makes it simple to identify the gaps. The findings organized under six main subtitles, the existing hardware, software, network, people, data and procedure/ management.

4.2.1.1. Hardware

In each health facility and at regional health bureau there is at least one idle desktop computer which is functional. In addition to this, the organization has financial resource which can make the health facilities and the regional health bureau equipped with necessary additional hardware. The main problem is that there is no specific requirement of hardware stated previously in the organization. Moreover, there is no structural design for the medical equipment information management system.

Table 4.1: Hardware Inventory of the Existing System

S. no	Location	Quantity	Type and model of computer	RAM	Hard disk	Processer	Purpose
1	Biomedical Department	1	Dell OptiPlex 700 cori3	4GB	500 GB	32bit Intel R Core (tm) CUP 2.53GHz	Office purpose
		1	Toshiba Satellite C55-b-896	4GB	500 GB	32 bit	ME Inventory \ Record
2	Dilchora Hospital	17	HP	2GB	500 GB	32bit, 3.2GHz	-Office Purpose -Patient Medical Record Purpose
3	Sabiyan Hospital	15	HP	2GB	500 GB	32bit, 3.2GHz	Office Purpose -Patient Medical Record Purpose
4	Gendkore H. C.	10	HP	2GB	500 GB	32bit, 3.2GHz	Office Purpose -Patient Medical Record Purpose

4.2.1.2. Software

Currently the organization is not using any specific software application related to the medical equipment information management, but the organization has plans to get a software application to help them in the management of medical equipment in the near feature (interveiw,1).

4.2.1.3. Network

The regional health bureau and the corresponding public health facilities are not interconnected by the network, but almost all urban public health facilities and the regional health bureau have a broadband internet connection within their organization. RHB internet capacity is 4GB. Dilchora hospital has 2GB internet connection. Sabiyan hospital has 2GB and Gendkore health center has 2GB. This internet availability can be valid opportunity in the implementation of web based medical equipment information management system.

4.2.1.4. People

Under the regional health bureau curative and rehabilitative core process, there are two biomedical engineers and two biomedical technicians in the pharmaceutical and medical equipment management and maintenance case team. They are responsible for the management and maintenance of medical equipment available in all public health facilities within the region. They use the workshop of Dilchora hospital as maintenance center. All the professionals have at least basic computer application skills.

4.2.1.5. Data / Process

As the interviews and document reviews show, there is no enough documentation on medical equipment performance, maintenance, down time, and replacement, especially after the equipment were issued to the facilities. In 2003EFY a general inventory was done by the Regional Health bureau for the purpose of knowing the available equipment type in the region. The second inventory is done in 2007EFY. The inventory formats being used includes the following information, inventory number, type of equipment, manufacturer, model, serial no., country of origin, year of manufacturer, power requirement, spare part availability, manual available, location, and equipment user. Due to absence of organized document preventive maintenance was not being done as per the equipment manufacturer standard. There are no records kept about the corrective maintenance being done.

Generally, the existing documentation system does not give complete information about equipment current situation, nor does it give previous equipment life history.

4.2.1.6. Procedure

Figure 1 shows the organizational structure of the regional health bureau. It points the exact position of the biomedical case team, who is responsible in the overall management of medical equipment in the region. The process of managing medical equipment among the facilities of the region is limited only on the stores, in which the information on medical equipment received or issued by the stores are recorded using model 19 and model 22.

4.2.1.7. Management

4.2.1.7.1. Vision of the Department

To see a healthy, productive, and prosperous Dire Dawa society.

4.2.1.7.2. Mission of the Department

To reduce morbidity, mortality, and disability thought providing an express and qualitative curative and rehabilitative health service in collaboration with Stakeholder (37).

4.2.1.7.3. Responsibility of the Department

The responsibilities of the department are planning, procure, distribute drugs and medical supplies including equipment and control over all management throughout the region(37).

4.2.1.7.4. Job Description of the Professionals

The biomedical professionals are responsible in performing the following tasks(37).

- Planning on the usage and maintenance process of medical equipment.
- Requesting spare part procurement for maintenance service.
- Provide on-site maintenance service throughout the public facilities.
- Assist with an equipment specification plan.
- Provide training for health professionals on equipment usage.
- Reporting about medical equipment needed to be replaced or discarded to the responsible body.

- Preform annual medical equipment inventory.
- Make general performance report.

4.2.1.7.5. Communication

The biomedical department has direct communication way with the facilities. Facilities make requests for corrective maintenance or consultancy verbally to the department.

Organizational Structure

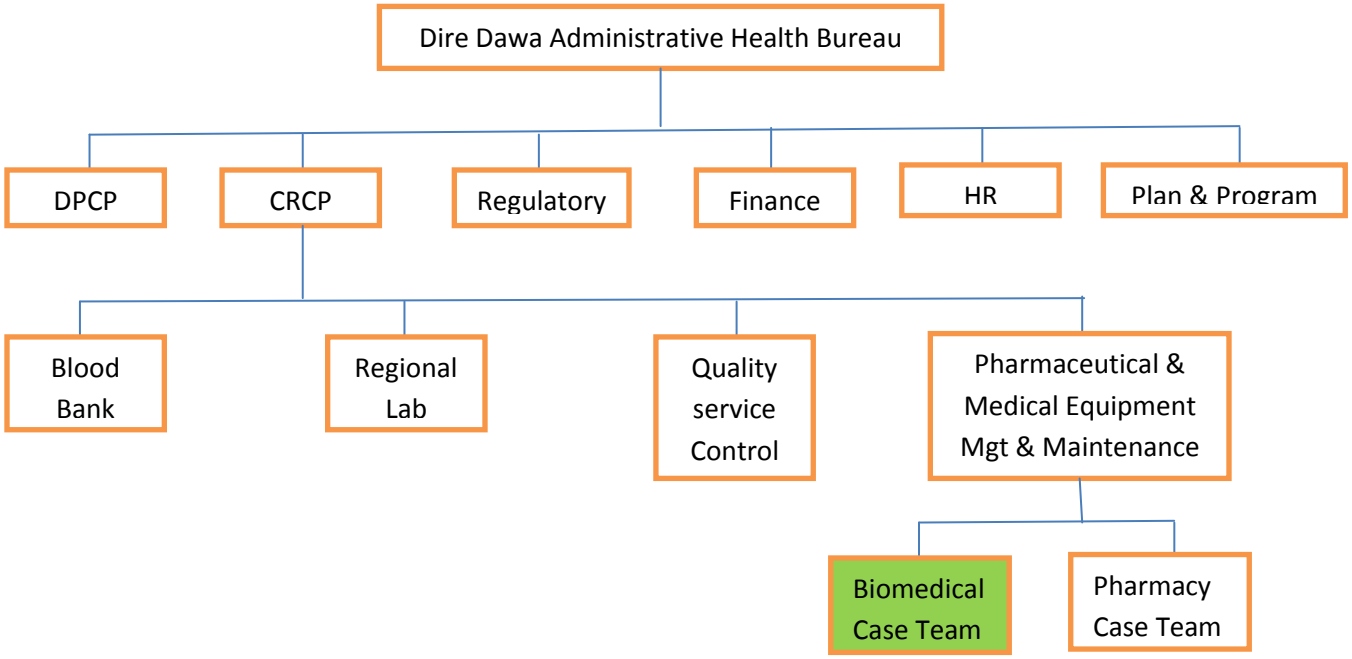


Figure 4.1: The Organizational Structure Of Dire Dawa Administrative Health Bureau

Generally, the existing system does not have a preventive maintenance tracing mechanism, there is no records on corrective maintenance done and spare part used. The corrective maintenance work order request made verbally to the central biomedical department. The business process of the existing system is limited only to the receiving and issuing process of the pharmacy store. The central biomedical department has no controlling mechanism over the performance and maintenance of the medical equipment. Therefore, to manage the medical equipment performance, maintenance, down time, and on time replacement of equipment, it is important to have strong medical equipment information management system which

keeps records and provide reports about the medical equipment in all public health facilities of the region.

4.2.2. Proposed System

The proposed system is applicable to the health facility and central Biomedical department. It will be implemented using client/ server based system architecture. A computerized equipment maintenance system might include equipment inventory module, spare part inventory module, and maintenance module in addition to other optional modules (3). Hospital medical equipment management guide has stated nine operational standards for medical equipment management. From these nine standards the three indicate that a hospital must have a paper based or computer based equipment and spare parts inventory management system and equipment history file (11). Depending on these documents and from the assessment findings of the current system, the investigator decided to make the new Medical Equipment Information Management System (MEIMS) to include medical equipment registry, spare part registry, preventive maintenance record, corrective maintenance record, and general report modules.

4.2.2.1. Context Diagram for the New MEIMS

Figure 2 present the context diagram of the proposed system, which is a top level view of the information system that shows the system's boundaries and scope. It also shows how the system interfaces with the outside world.

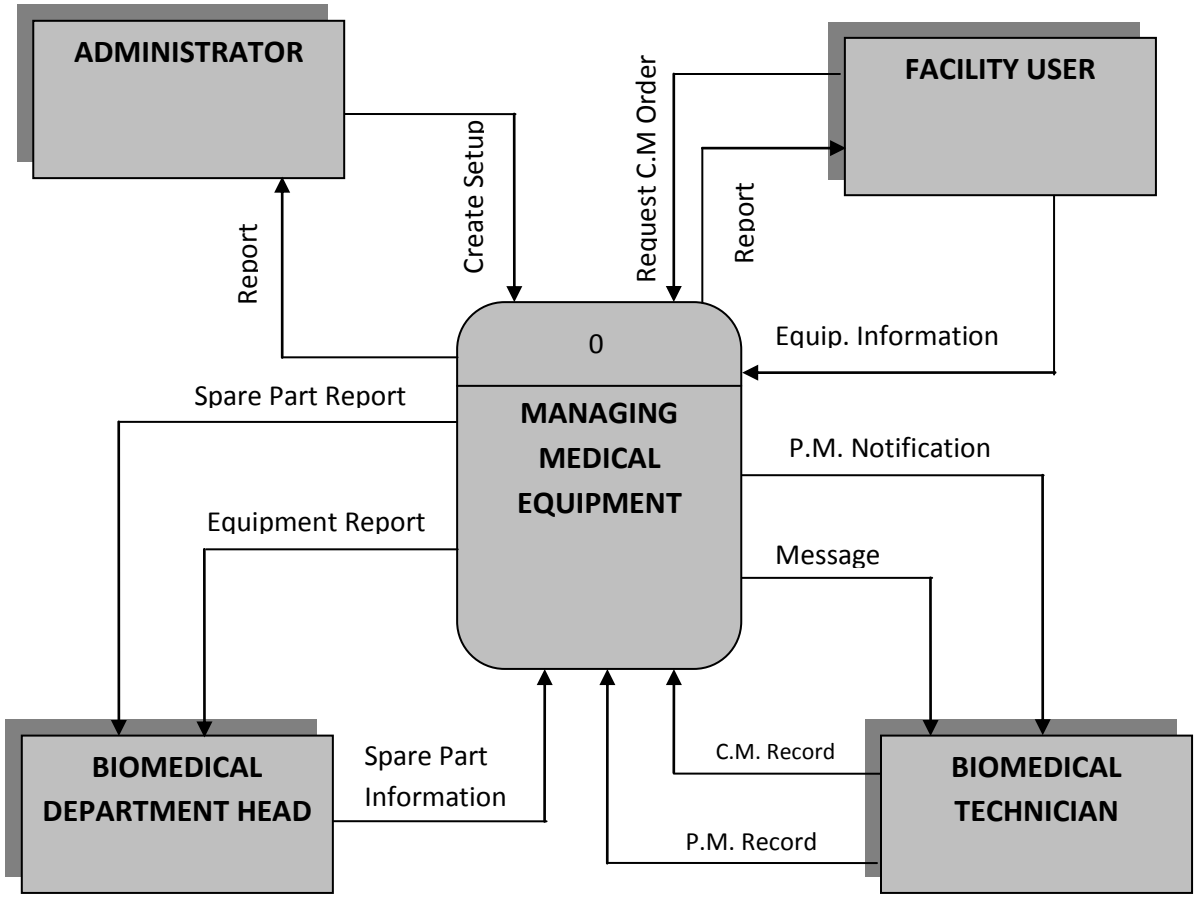


Figure 4.2: Context diagram for Medical Equipment Information Management System

4.2.3. Stakeholders

Stakeholders are individuals or organizations that could influence or be influenced positively or negatively by medical equipment information management system.

Table 4.2: List of stakeholders and their roles and responsibilities

S.n	Stack holders	Role and Responsibilities
1	System Administrator	-Responsible for creating and updating user account , organizational setup, Manufacturer setup, supplier setup and department setup.
2	Facility focal Person	-Responsible for medical equipment information registry -Responsible for sending a request for corrective maintenance work order -Responsible for requesting the system to generate reports and use the report at the point of service.
3	Biomedical Technician	-Responsible in recording preventive and corrective maintenance details. - Responsible for registering spare part information. - Responsible for generating reports and use the report in the improvement of service provision.
4	Biomedical department head	-Responsible for generating equipment report. - Responsible for disseminating the report for decision making bodies. - Responsible for facilitating overall activities in the biomedical department.
5	Health Professional	- Responsible for providing appropriate information about medical equipment performance and incidence
6	Health Facility Management	- Responsible for providing administrative and infrastructure need - Responsible for interpreting reports and make a decision at the facility level
7	Curative Department Head	-Responsible for controlling overall medical equipment management information system at the regional level -Interpret and use the report for decision making purpose at regional level

4.2.4. System Analysis Models

The following use cases have been identified from the new proposed system specification.

- Login
- Create an account
- Register medical equipment
- Register spare parts
- Produce preventive maintenance schedule
- Record preventive maintenance Information
- Complete corrective maintenance work order
- Record corrective maintenance record
- Generate standard report
    - Corrective Maintenance Report
    - Preventive maintenance Report
    - Medical equipment Report
    - Spare Part Report

4.2.4.1. Use Case Diagram

To create use case diagram for the proposed system, the investigator tries to identify what process should be included in the system, depending on the document reviewed and existing system assessment findings. Then she describes how many use cases should all the process be presented and identifies if there is an association between any of the use cases. The investigator identifies the primary and the secondary actors for each use case and relates each actor with its corresponding use cases.

During identifying actors in the system use case, actors who are responsible in recording medical equipment, requesting corrective maintenance work order and administrator are not available in the existing organizational situation. The second point discovered in this process is, the system boundary overlaps somehow with the pharmacy store process.

The following diagram shows all the use cases identified from medical equipment information management system process. It also shows the actors of the system as well as the boundary.

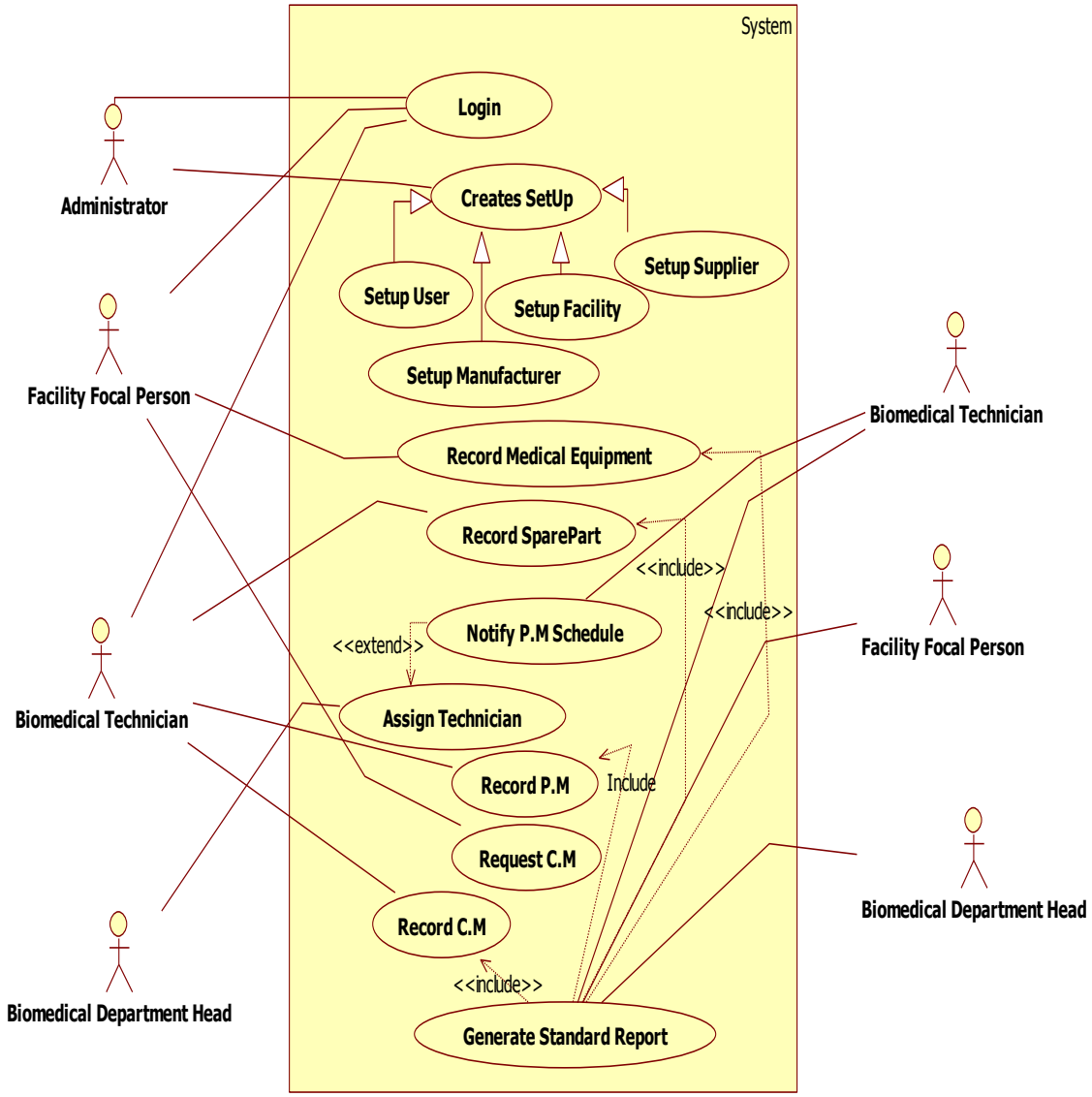


Figure 4.3: System Use Case Diagram for Medical Equipment Information Management

4.2.4.2. Use Case Narrations

The narrations of use cases are used to illustrate each use case or process identified in a use case diagram. It is very helpful to make the end user to understand the process of the system. In this case all the processes are narrated along with its actors, trigger point, the output of the processes and so on. The sample of the use case narration and activity diagram are presented in the following figures, the whole document is available in appendix A.

4.2.4.3. Activity Diagram Modeling

The activity diagrams are used to illustrate the process of the system in a diagrammatic form. It helps to present the process in a sequential order.

The following activity diagram shows all objects within the medical equipment information management system and their interaction with the system.

Use Case ID:	**UC-03**
Use Case Title	Register medical equipment
Use case Description	This use case describes the process of registering electronic medical equipment information.
Primary Actor	Facility focal person
Trigger	The focal person attempts to register medical equipment by selecting the medical equipment option from system main menu
Pre-Conditions	The user is logged in to the system
Post-Conditions	Medical equipment information is recorded in the system database. The equipment is assigned a unique ID.
Main scenario	1.The user selects medical equipment recording menu option; 2.The system displays medical equipment recording form; (Figure 4.21) 3.The user fills the form with equipment information; 4.The user clicks submit button; 5.The system saves the equipment information on the system database and make the form ready for the next record;
Alternative scenario	4.1. If the user clicks on cancel button; 5.a. The system return to the main menu; 4.2. If the user clicks on reset button; 5.b. The system clear the input box;
Frequency of Use	About 40 per month
Business Rule	

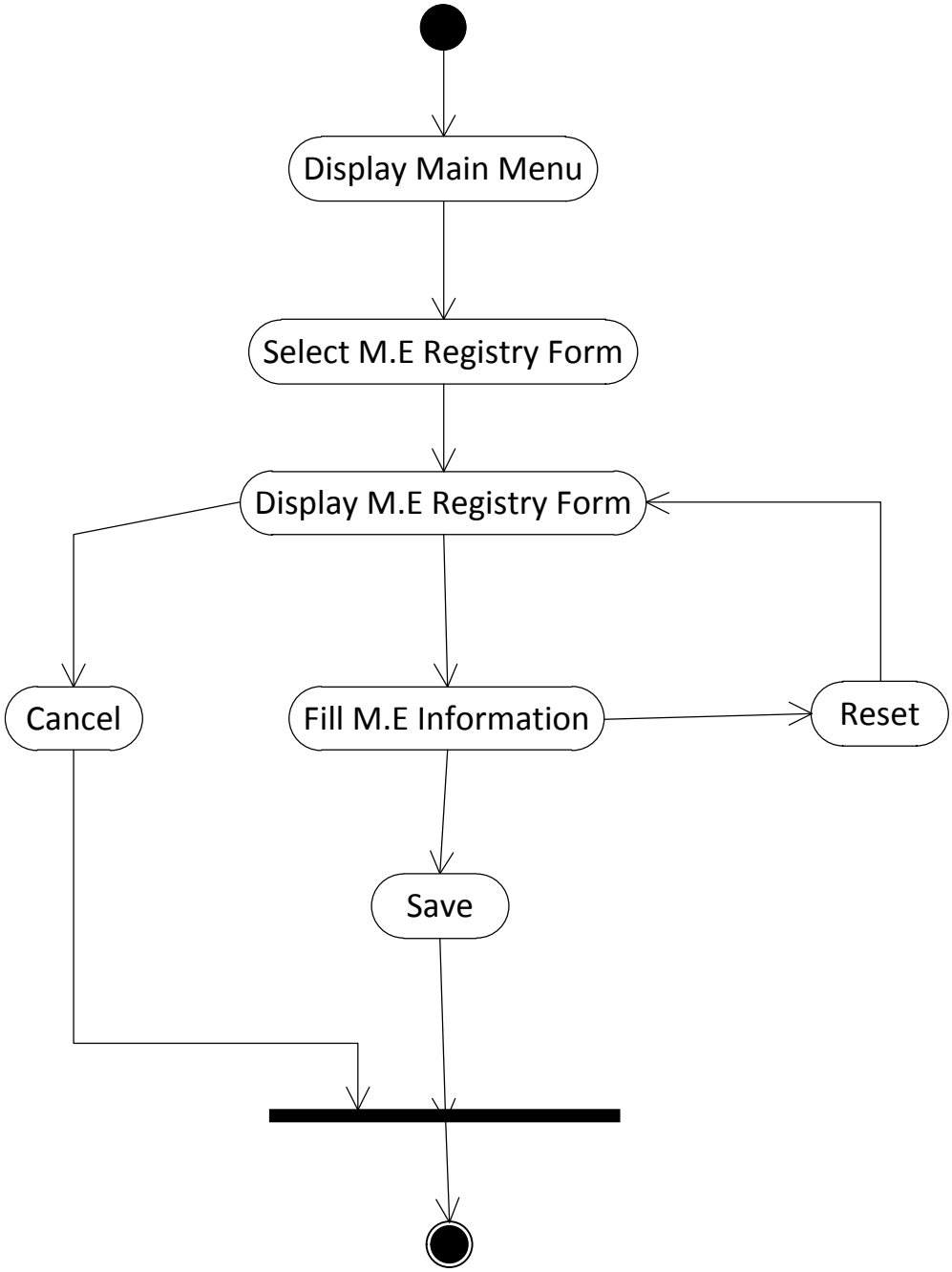
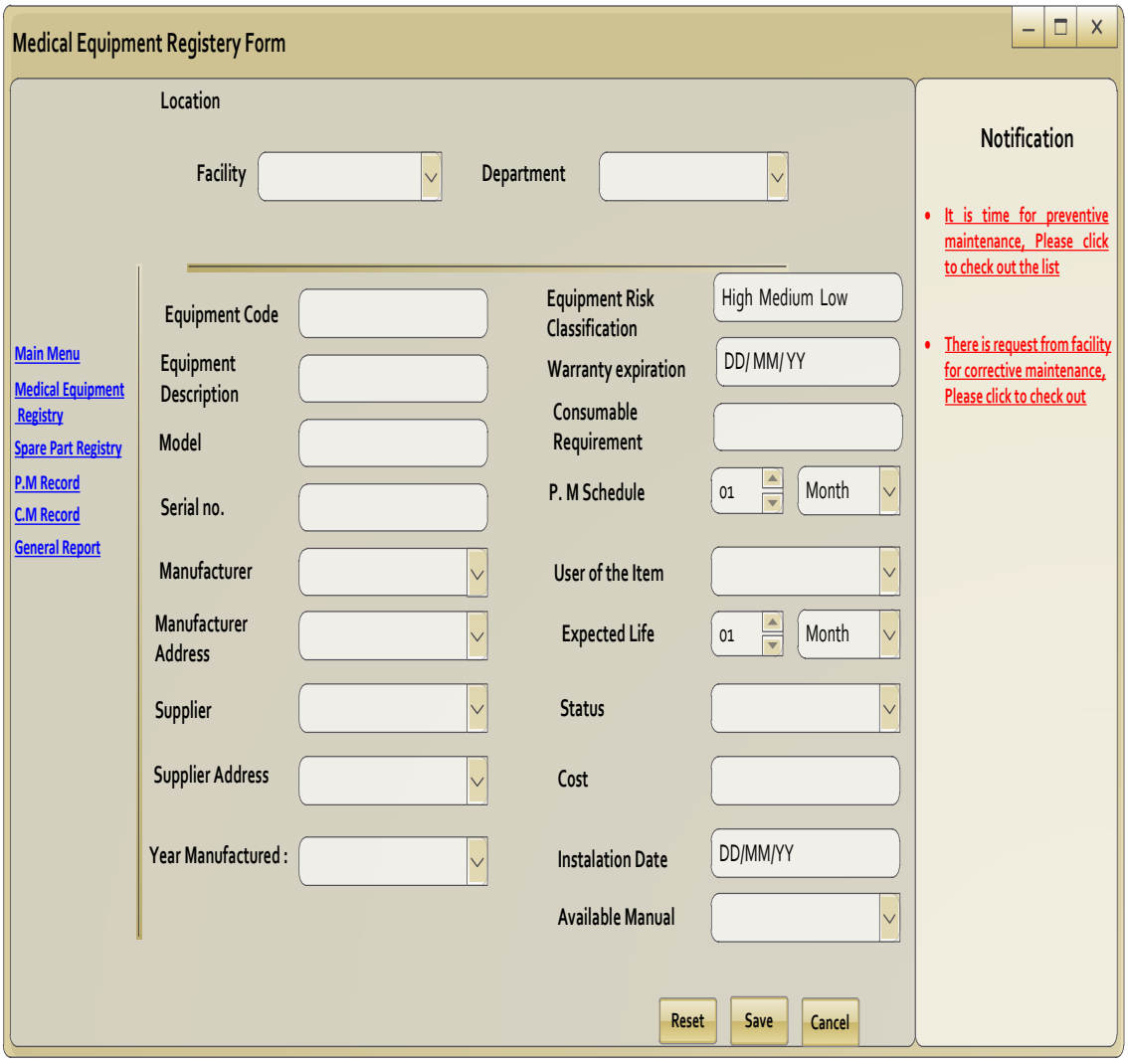


Figure 4.4: Activity diagram for medical equipment registering process

4.2. User Interface Prototype

User interface prototype is a model used to simulate the system user interface at an early stage of the system design. It can be developed using hand drawing or CASE tool like Visio. It helps to make the end user to test the system at an early stage and identify the gaps in very low cost and time. It also helps to communicate ideas between designer, developer, users and stakeholders. The following sample user interface prototype is developed using Visio presents the new system, the rest total document is found in Appendix A.

User Interface Prototype ID: UIP-03



4.2.5. System Requirements

Requirement constitute a specification for the new system. It is the starting point for measuring the performance, accuracy, and completeness of the finished system before entering the system design. In system analysis, it is important to identify the functional and Non functional requirement.

4.2.5.1. Functional Requirements

Functional requirement describes the interaction between the system and its users, and between the system and any other systems which may interact with the system by supplying or receiving data (38). The high level functional requirements identified in the new system are listed as follows.

Table 4.3: Functional requirement list

Req. ID	Requirement Description	Requirement Source	Ranking	
			Mandatory	Optional
01	The system should differentiate the ordinary user and administrator	UC-01	X	
02	The system should enable authenticated user to log in to the application	UC-01	X	
03	The system should enable the user to register medical equipment information	UC-03	X	
04	The system should enable the user register spare part information	UC-04	X	
05	The system should provide preventive maintenance schedule notification	UC-05	X	
06	The system should enable the user to record preventive maintenance information	UC-07	X	
07	The system should allow the user to send	UC-08	X	

	corrective maintenance request			
08	The system should enable the user to record corrective maintenance information	UC-09	X	
09	The system should enable authenticated user to edit and delete records	UC-02	X	
10	The system should generate all types of standard reports	UC-10	X	
11	The system should enable the administrator to create, delete, update user setup	UC-02	X	
12	The system should enable the administrator to create, delete, update facilities setup	UC-02	X	
13	The system should enable the administrator to create, delete, update Manufacturer setup	UC-02	X	
14	The system should enable the administrator to create, delete, update Supplier setup	UC-02	X	

4.2.5.2. Non functional Requirement

Non functional requirement describes how well the system supports the functional requirement. It describes not what the software will do, but how the software will do it (38). The new system is expected to include the following nonfunctional requirement, performance criteria, the reliability requirement, security consideration, interface requirement, and error handling.

Table 4.4: Non Functional requirement list

Req. ID	Requirement Description	Requirement Source	Ranking	
			Mandatory	Optional
01	The system shall provide 8 hours per day service	Interview(1,2)		X
02	The system shall uses English language	All User interface	X	
03	The system shall provide error message Whenever the user attempts to enter invalid data	(Figure 4.31)	X	
04	The system shall provide notification message whenever the user leave crucial text box empty	(Figure 4.21)	X	
05	The mean time between failure must be 3 month	Reference No. 39	X	
06	The average user learning time must be less than 1 day	Reference No. 39		X
07	The system shall be available 99.99% of time	Reference No. 39		X
08	The system shall be modifiable	Reference No. 39		X
09	The system shall use client server system architecture	Reference No. 39	X	

4.3. System Design Models

4.3.1. System Class Diagram

To design MEIMS the investigator uses class and sequence diagrams. The class diagram uses to present the system classes (object), their attributes, association between classes, attribute type, class methods (what a class can do), navigability of class, and dependency between classes. The investigator tries to identify all the classes by taking all noun words from the narrated use cases defined previously and differentiate the words that should not be a class. After identifying all possible classes, the second step was looking for the association between each class. The class identified were, 'UserAccount' class, which is inherited by 'User' and 'Administrator' class. 'Department', 'Supplier', 'Facility' and 'Manufacturer' classes are managed by the administrator class. The class 'Registration' captures the information of 'Equipment', 'Sparepart', 'PreventiveMaintenance', and 'CorrectiveMaintenance' classes. The rest of the interface class 'Report' and class 'C.Mworkorder' are performed by the class 'User'. Depending on the existing system document and literature reviewed, the attributes of each class were identified by their type. The attributes are used as an identity for a class. The functions of all classes were identified as well as the parameter they get or set using the narrative use cases as a reference.

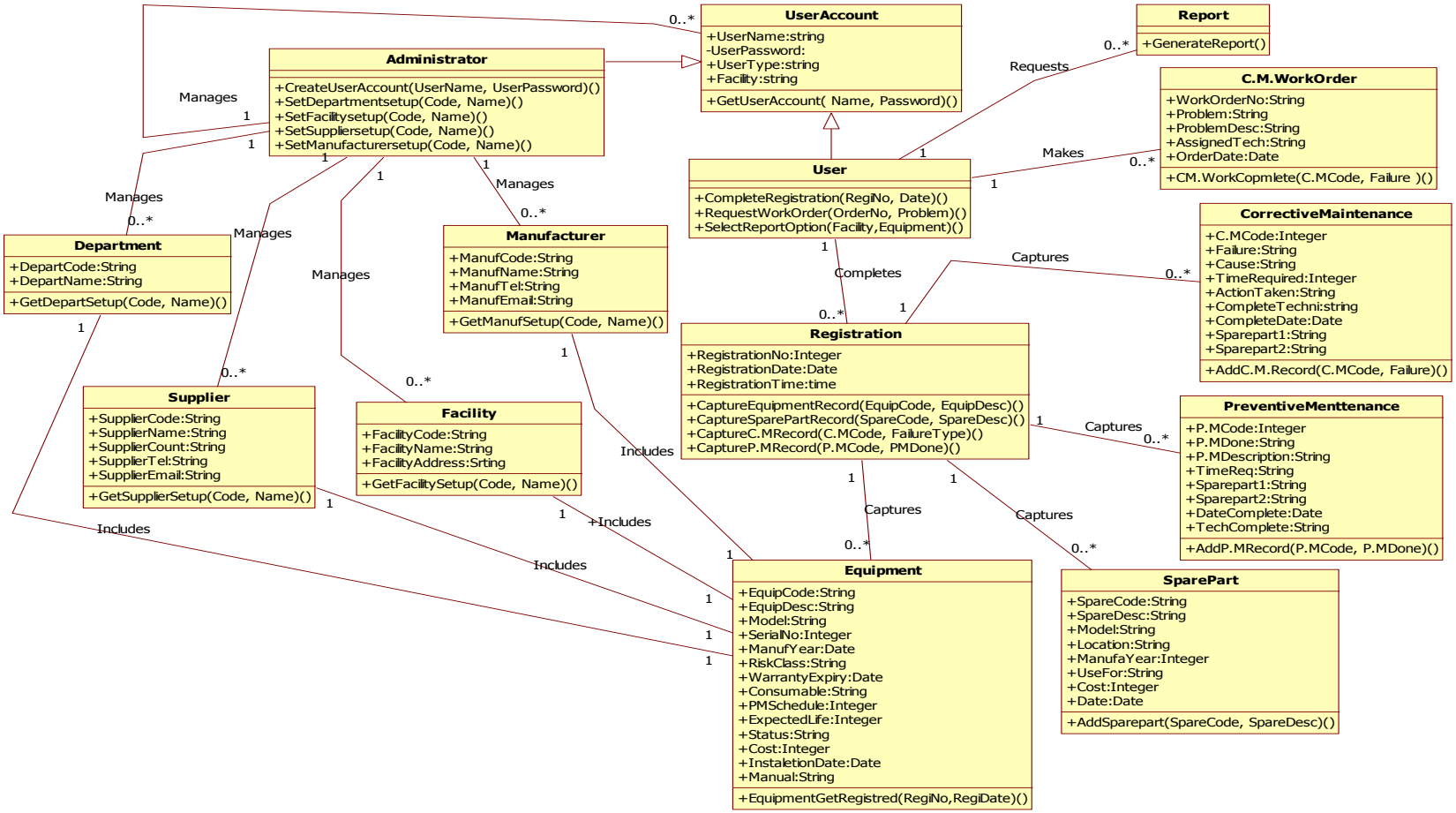


Figure 4.5: Class Diagram for Medical Equipment Information Management System

4.3.2. Sequence Diagrams

Depending on the class diagram, the use cases, and the objects identified previously, the sequence diagrams were used to clarify the flow of process within the system. Each method of a class was presented with its parameters to be passed. The sequence diagram of the system presents all objects found in each use case model of the system and their interaction with the system in a sequential order of their occurrence. The following figure shows a sample of sequence diagram for the system, the whole document is available in appendix A.

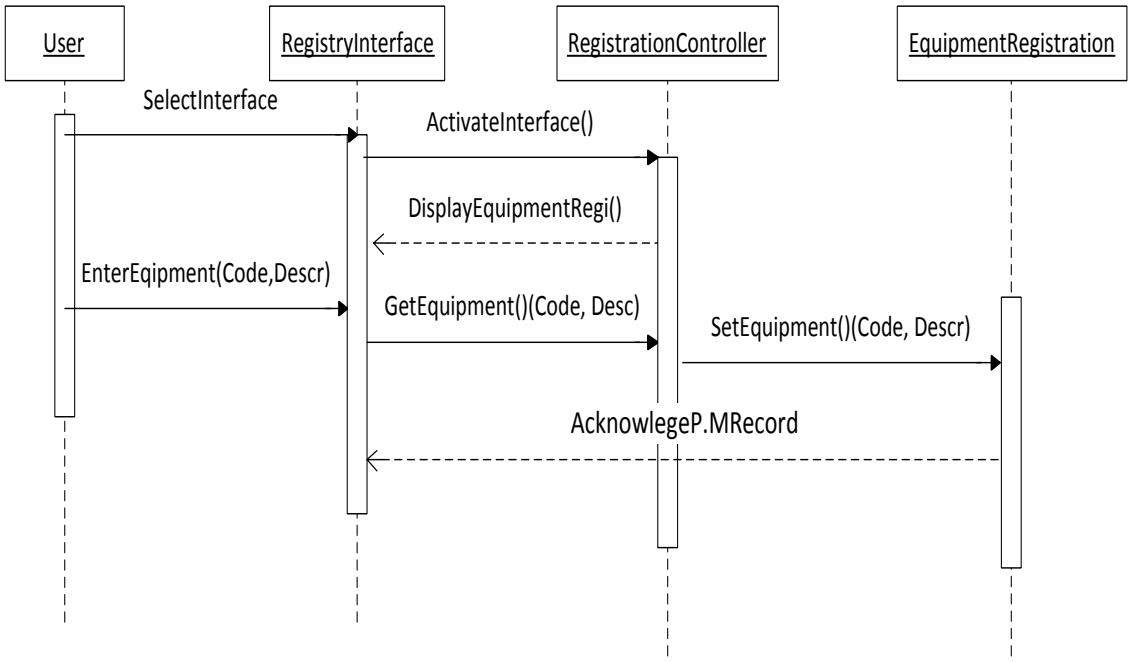


Figure 4.6 : Sequence diagram for the process of registering medical equipment

4.3.3. System Architecture

System architecture translates the logical design of an information system into a physical structure (21). This medical equipment information management system is designed to have a three tiers Client/Server architecture. The client/server architecture refers to systems that divide processing between one or more networked clients and a central server. In this system, the client handles the entire user interface, including data entry, data query, and screen presentation logic. The server stores the data and provides data access and database management functions. Application logic is divided in some manner between the server and the clients. In a client/server interaction, the client submits a request for information from the server, which carries out the operation and responds to the client. Only the request and the result are transmitted across the network.

The investigator proposed the Client/Server system architecture because, the Client/Server is cost effective in large scale networks, flexible, and scalable (21).

The following diagram represents the planed system architecture design for medical equipment information management system.

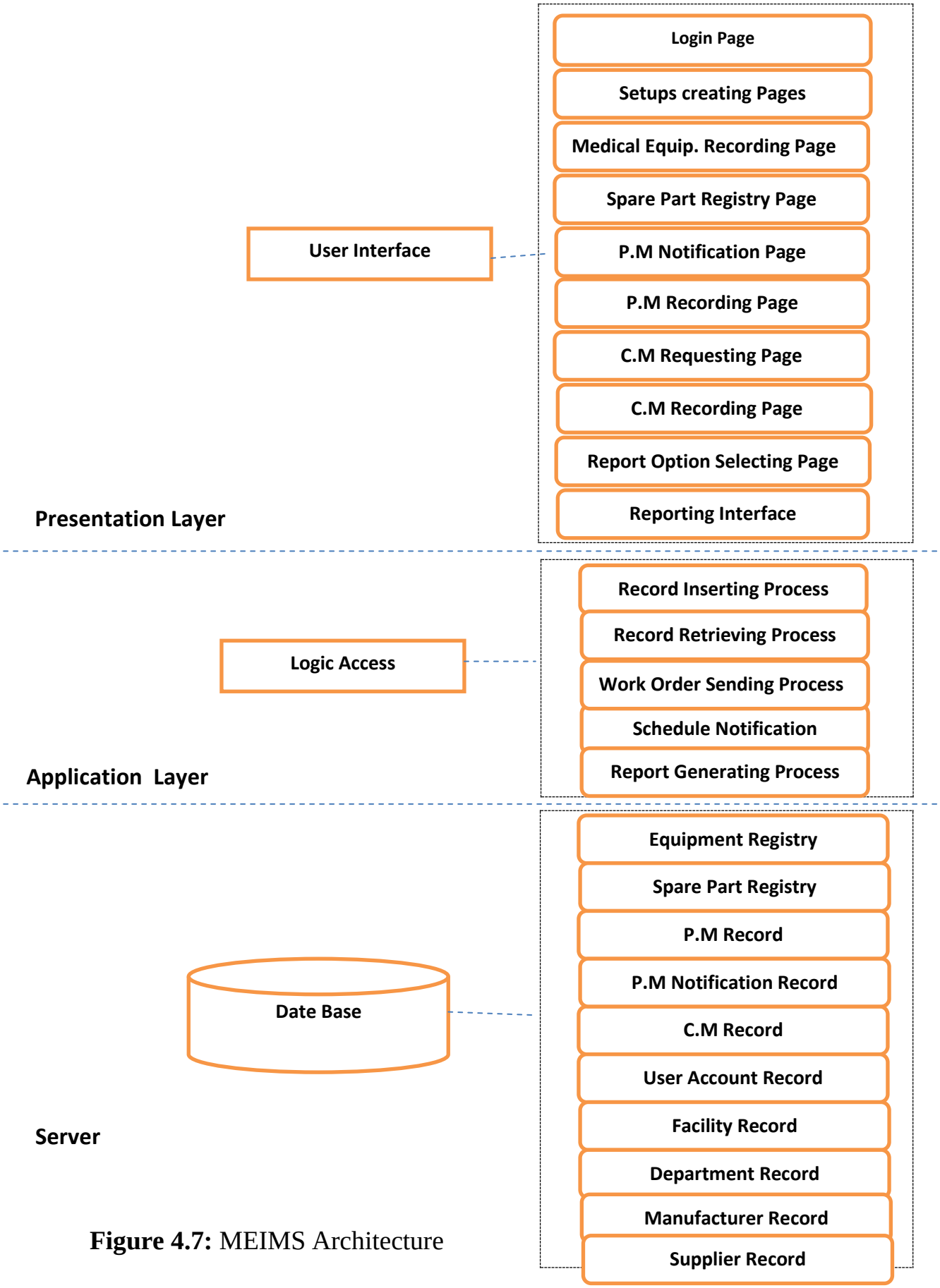


Figure 4.7: MEIMS Architecture

4.4. Prototype Implementation

The implementation of MEIMS is done in three parts, the presentation layer, Database layer, and the middle layer. The user interface/ presentation part is implemented using HTML and CSS coding. The database is developed using MySQL database management system and the middleware, which connects the user interface and the database, is implemented using PHP. The following snapshots present some of the user interface of the system.

4.4.1. Presentation Layer

4.4.1.1. Medical Equipment Registry Form

Medical Equipment Registry allows the user to register new medical equipment information into the system. To open the registry form, it only needs to select medical equipment option from the main menu. It contains all information about a specific equipment need to be capture. The following is the sample of the form all the document is available in appendix A.

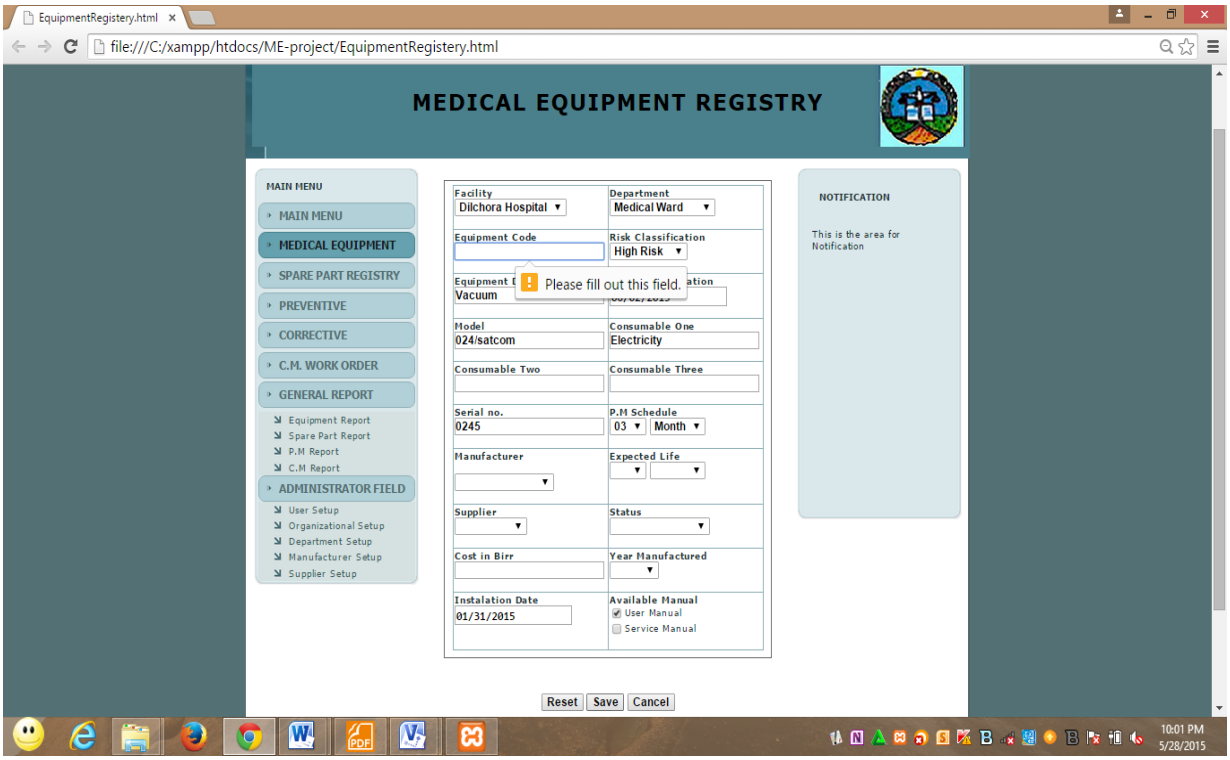


Figure 4.8: Medical Equipment Registry Form

4.4.1.2. Usability Testing for User Interface

Usability Testing aids, to identify whether the system satisfies the requirements of its end users. In the case of MEIMS design, usability testing is done initially by using the user interface to identify the gaps of the requirement need to be achieved by the system as early as possible. The testing is done by introducing closed ended questions to the end user of the organization. It participates five users after explaining the use of the test and how to use the user interface. This test is the initial test to be done in the first iteration of the system development process and which should be continued in each iteration until the system achieves the specified requirement. The following table shows the summarized results of the test done by the five participants.

Table 4.5: User Interface Test Result

S. no	Test Questions	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1	The interfaces are attractive			2	3	
2	I like the color of the interface				3	2
3	The font of the interface are Good				4	1
4	The sequence of the interface is clear			2	3	
5	All important content addressed well				2	3
6	There is too much inconsistency in the system interface		4	1		
7	I found the interfaces are very cumbersome to use		4	1		
8	The interfaces are easy to understand			1	4	
9	I need more time to learn it			2	3	
10	There is unnecessary content available in the interface		5			

Generally, the users agree with most parts of the interface, but still there are some more need of improvement to achieve user requirements. The point the user not satisfied at being attractiveness, sequence, consistency and the learnability of the user interface. Therefor it should be reviewed again to identify the specific gaps and put a solution.

4.4.2. Database Layer

4.4.2.1. Database Model

Depending on previously designed class diagram, data storage area is created using tables in the database. All fields of table are identified and the corresponding primary key within each table. The primary key is used to identify a specific record within a table. To create a simple, flexible, and free of data redundancy, normalization is done on the tables. "Normalization is the process of creating tables designs by assigning specific fields or attributes for each table in the database" (21). After passing through a different normalization stage of the tables, the database is modeled using relational model. The relational model uses a foreign key to establish relationships between tables and form an overall data structure. The relational database is used because it is well suited to client/server computing(21). The created tables include Equipment Registry, Spare Part, Corrective Maintenance, Preventive Maintenance, Work Order, Equipment list, Facility, Department, Manufacturer, Supplier, User Account tables.

4.4.2.2. Physical Storage

The physical storage involves a physical record or block, that can be handled by the operating system at a time. The storage can be located in different areas. In the case of this system the storage is located on a web based. A physical record can contain many logical records, which is a set of field values that describes a single record in a table regardless of how or where the data is stored.

The following figure 4.9 illustrates the overall storage tables along with their relationships. The details of physical data model of MEIMS database are presented by figure 4.10.

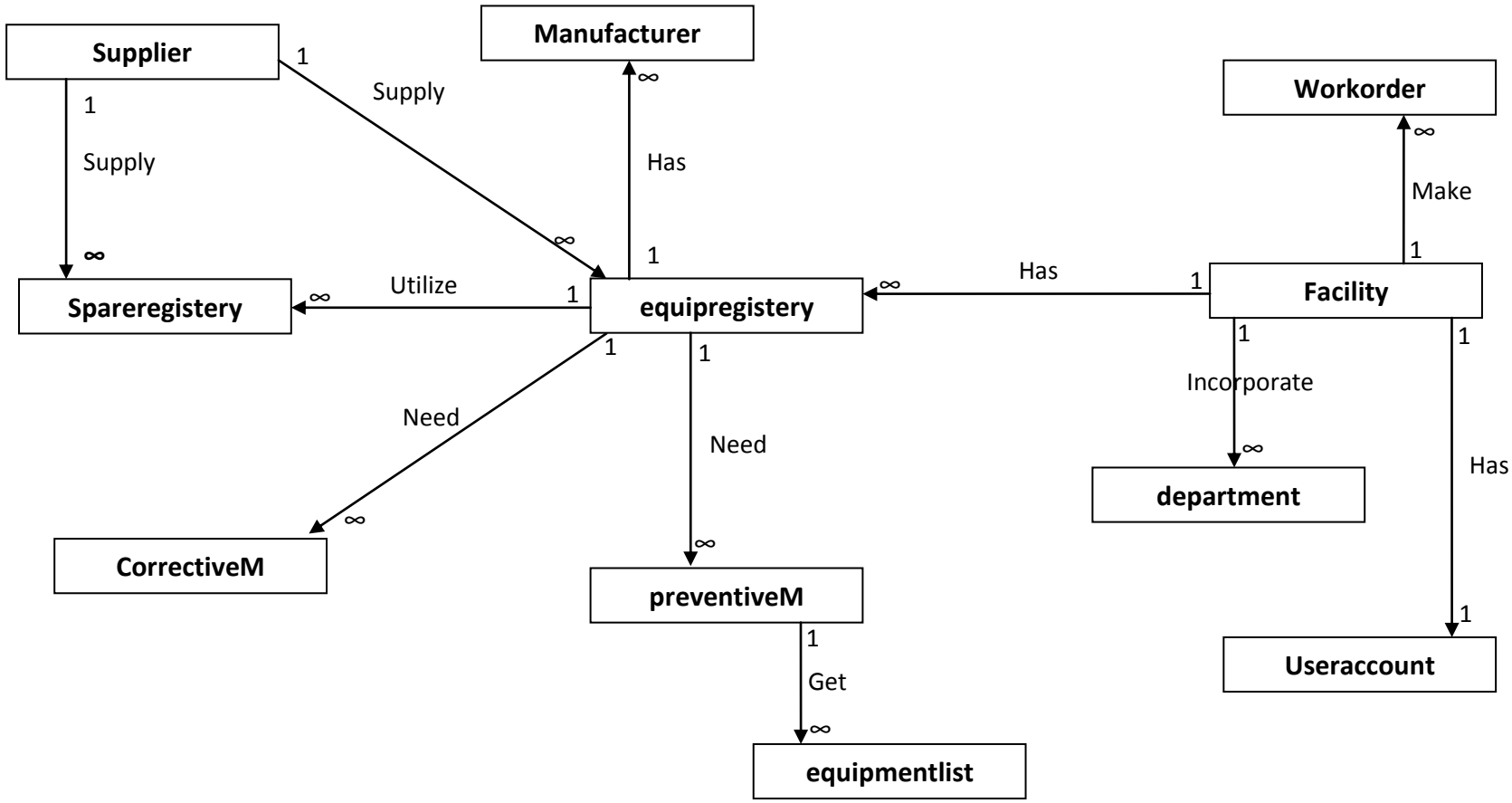


Figure 4.9: Overall storage tables and their relationships to each other

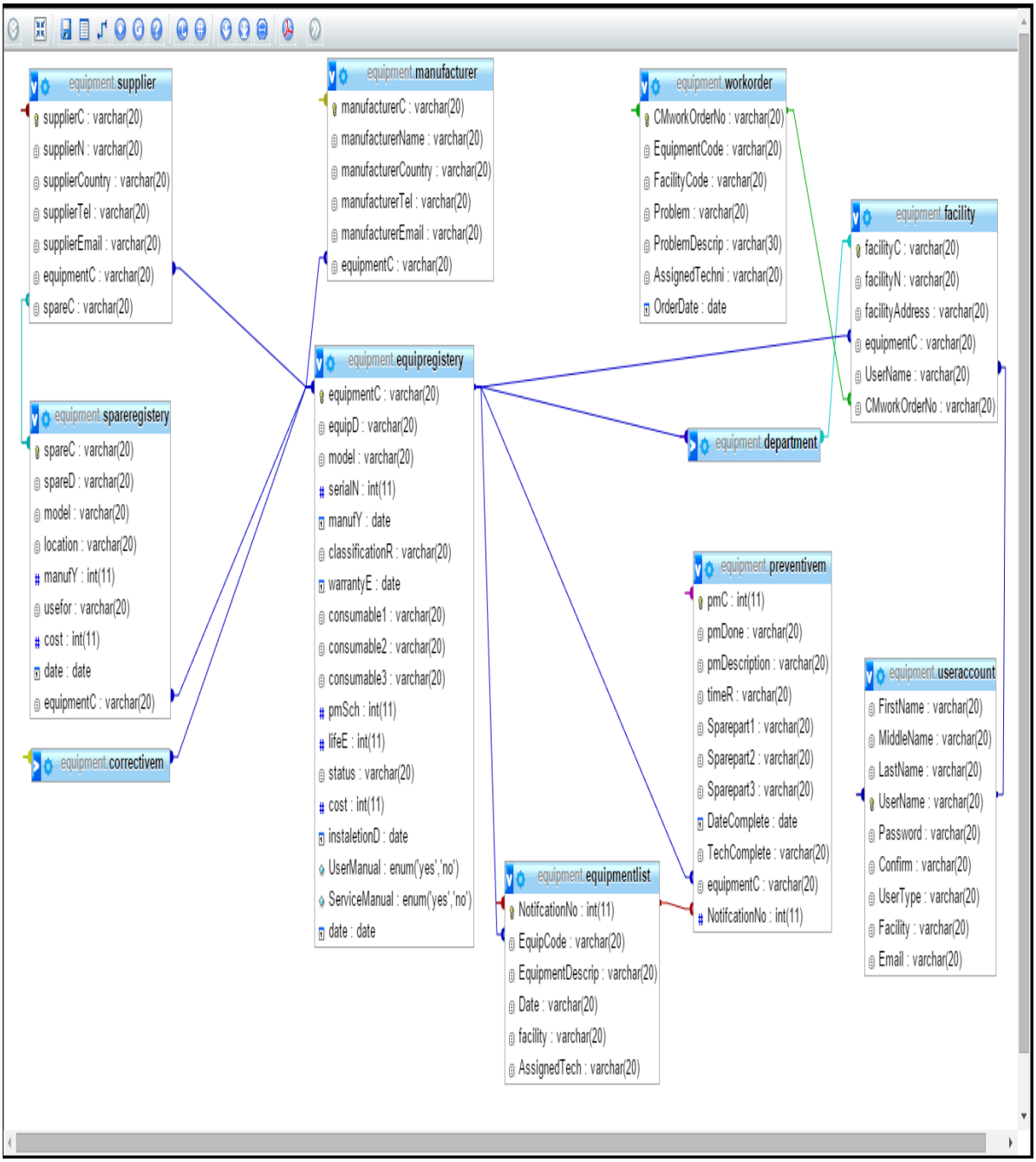


Figure 4.10: The physical Database Model of MEIMS

4.4.3. Middle Layer

To connect the user interfaces and the database created, PHP codes are used that embedding in the HTML. The following snapshot presents the sample of this cods.

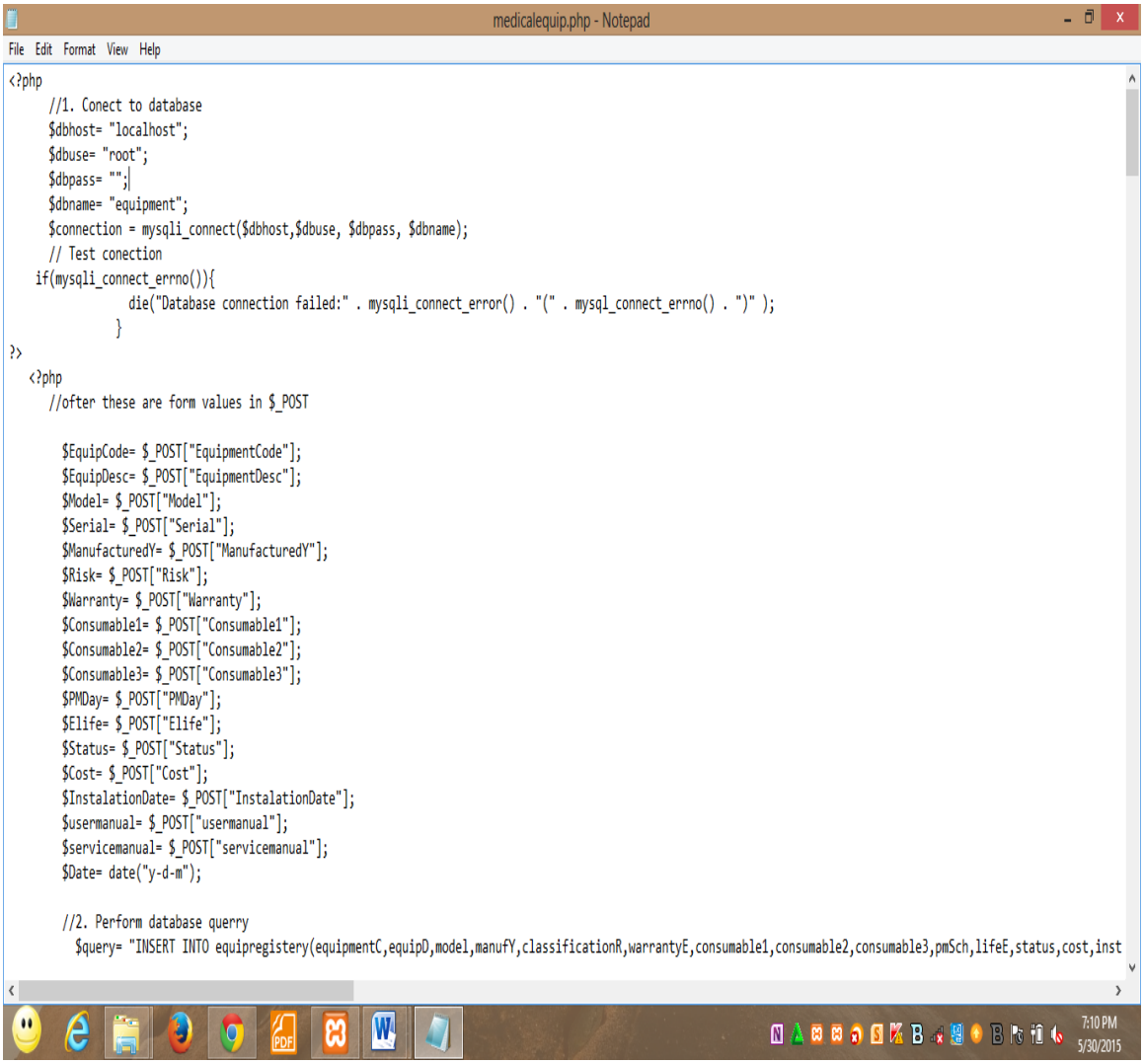


Figure 4.10: Sample of PHP Cods

Chapter Five

5. Conclusions And Recommendations

5.1. Conclusions

MEIMS is a system that records all the information on medical equipment available in the piloted urban public health facilities. The information includes the life history of the medical equipment, preventive and corrective maintenance of the equipment, the cost for the maintenance and records for the spare part availability. The system supports following the performance of specific equipment and its life cost. It also provides an information for planning and decision making in management.

This project represents the first step towards developing MEIMS. As it follows an iterative process, it shows the first blueprint of the iteration that will be improved through the cyclic development process of the project until it satisfies the user of the system.

In the process of analysis and design this system, the investigator recognizes that the boundary of the system somehow overlaps with the system of pharmacy store, which captures the information of medical equipment at initial. The existing system documentation is not well organized and complete, that makes the investigator depends on literature to design the system. A manual documentation system is a base for implementing the new system. It is identified that the system may need additional human resource specially at the health facilities, who will be responsible in implementing the system. There are some opportunities identified like computer hardware and internet access at the central office and the piloted three facilities, though they need to be scaled up in capacity. In designing process, the security issues and hardware design were not well addressed by this project. The user interface of the system needs to be improved according to the test result identified.

Generally, this project does not show the final product of the system, rather provides system prototype for further continuous evaluation and development along with the user feedback input.

5.2. Recommendations

Dire Dawa Health Bureau

The health bureau is recommended to initiate the revision of the pharmacy store computer system by;

- Reinforcing the supporting stakeholder to include medical equipment information into the system and,
- Scale up the system to support the management of equipment performance after the installation.

The bureau is recommended to strengthen the documentation system centrally and at the facility level by;

- Including all important information in the documentation and,
- Reinforcing the biomedical technicians to keep records of preventive and corrective maintenance, during receiving and handover equipment, and spare part used for maintenance.
- The organization should plan to assign one responsible person at the facility level to organize and manage medical equipment information

In addition to the fulfillment of important infrastructure for the implementation of web base MEIMS, it is recommended to scale up the existing computer hardware to be used by the system as follows,

For front end web server

Processor	RAM	Hardware
64bit, four core, 2.5 GHz	8GB	80GB
For application server		
Processor	RAM	Hardware
64bit, four core, 2.5 GHz	8GB/16GB	80GB
For SQL server tier		
Processor	RAM	Hardware
64bit, four core, 2.5 GHz	16GB	100GB

Ministry of health

The ministry of health should encourage the regional health bureau to implement MEIMS by identifying and coordinating with stakeholders to support the region.

Researcher

The investigator would like to recommend future researcher to;

- Put their effort on the analyzing and design a system which integrates the pharmacy store computer system with the medical equipment information system
- Implement this system by reviewing and addressing the security issue, the hardware design and usability testing of the system.

Addis Ababa University School of Information Science and School of Public Health

The investigator would like to recommend the school to initiate the ministry of health and regional health bureaus on the introduction of information technology in health by proving a short term training or workshops to build their attitude toward technology.

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Interview

1. With Mr. Mahdi Abdel , Pharmaceutical and Medical Equipment Department Head, March,2015, at Dire Dawa.
2. With Mr. Anteneh Berhanu, Biomedical Staff, March, 2015, at DireDawa.

Appendix A

Software Requirement Specification Document

For

Web Based Medical Equipment Information Management System

Chapter One

1.1. Introduction

In delivering the health care service, health professionals use different kinds of medical equipment to provide quality health care service. Medical equipment is any instrument, apparatus, implement, machine, appliance, implant, in vitro reagent or calibrator, software, material or other similar or related article which does not achieve its primary intended action in or on the human body by pharmacological, immunological or metabolic means. Medical equipment information management system used to automate the documentation of all activities relating to medical equipment. The Biomedical department or clinical engineering department is responsible in including and excluding medical equipment in the health technology management program for tests, repairs and maintenance. Appropriate management of medical equipment ensures safe and effective health service provision. Medical equipment information management system (MEIMS) used to automate the documentation of all activities relating to medical equipment. MEIMS incorporates equipment and spare part inventory modules, maintenance module, and contracts management module

1.2. Objective

The objective of this project is to design web- based information system for medical equipment management taking the Dire Dawa administration health bureau as a case.

1.3. Purpose

This system development provides different functionalities for different individuals. For the users it may make their work easier, effective and efficient by using information technology and make them to take one step forward. For the regional health bureau, it provides a system prototype ready for implementation and may help policy makers reach a decision regarding health technology.

1.4. Scope

This project is limited to the design of a web based medical equipment information management system and a system prototype thereafter. The project does not present a complete outstanding system rather it provides first a blueprint of the initial system development iteration process output. It also includes the initial user interface prototype testing. The medical equipment included in the management information system are those instruments, apparatus, machine, calibrator, materials and vitro reagent used for prevention, diagnosis, treatment and rehabilitation service provision for a patent, excluding implantable, disposable or single use medical equipment. The project uses an Object Oriented methodology as modeling method and the iterative process modeling as a process of analyzing and designing the system. The technique used in this system analysis and design are UML modeling techniques. To present the UML models and the user interfaces prototype of the system Visio and White Star CASE tools are used. PHP, HTML programming language and MySQL database management system are used to implement the system software prototype. The system architectural design is presented using three tire client server system architecture. The hardware requirement and network design are not included in this project.

Chapter Two

2. Functional Requirements

Requirement constitute a specification for the new system. It is the starting point for measuring the performance, accuracy, and completeness of the finished system before entering the system design. In system analysis, it is important to identify the functional and Nonfunctional requirement.

Functional requirement describes the interaction between the system and its users, and between the system and any other systems which may interact with the system by supplying or receiving data (38). The high level functional requirements identified in the new system are listed as follows.

Table2.1 Functional requirement list

Req. ID	Requirement Description	Requirement Source	Ranking	
			Mandatory	Optional
01	The system should differentiate the ordinary user and administrator	UC-01	X	
02	The system should enable authenticated user to log in to the application	UC-01	X	
03	The system should enable the user to register medical equipment information	UC-03	X	
04	The system should enable the user register spare part information	UC-04	X	
05	The system should provide preventive maintenance schedule notification	UC-05	X	
06	The system should enable the user to record preventive maintenance information	UC-07	X	
07	The system should allow the user to	UC-08	X	

	send corrective maintenance request			
08	The system should enable the user to record corrective maintenance information	UC-09	X	
09	The system should enable authenticated user to edit and delete records	UC-02	X	
10	The system should generate all types of standard reports	UC-10	X	
11	The system should enable the administrator to create, delete, update user setup	UC-02	X	
12	The system should enable the administrator to create, delete, update facilities setup	UC-02	X	
13	The system should enable the administrator to create, delete, update Manufacturer setup	UC-02	X	
14	The system should enable the administrator to create, delete, update Supplier setup	UC-02	X	

Chapter Three

3. Nonfunctional Requirement

Nonfunctional requirement describes how well the system supports the functional requirement. It describes not what the software will do, but how the software will do it (38). The new system is expected to include the following nonfunctional requirement, performance criteria, the reliability requirement, security consideration, interface requirement, and error handling.

Table 3.1. Non Functional requirement list

Req. ID	Requirement Description	Requirement Source	Ranking	
			Mandatory	Optional
01	The system shall provide 8 hours per day service	Interview(1,2)		X
02	The system shall uses English language	All User interface	X	
03	The system shall provide error message Whenever the user attempts to enter invalid data	Figure 4.31	X	
04	The system shall provide notification message whenever the user leave crucial text box empty	Figure 4.21	X	
05	The mean time between failure must be 3 month	Reference No. 39	X	
06	The average user learning time must be less than 1 day	Reference No. 39		X
07	The system shall be available 99.99% of time	Reference No. 39		X
08	The system shall be modifiable	Reference No. 39		X
09	The system shall use client server system architecture	Reference No. 39	X	

Chapter Four

4. System Modeling

4.1. System Analysis Models

4.1.1. Use Case Diagram Presentation

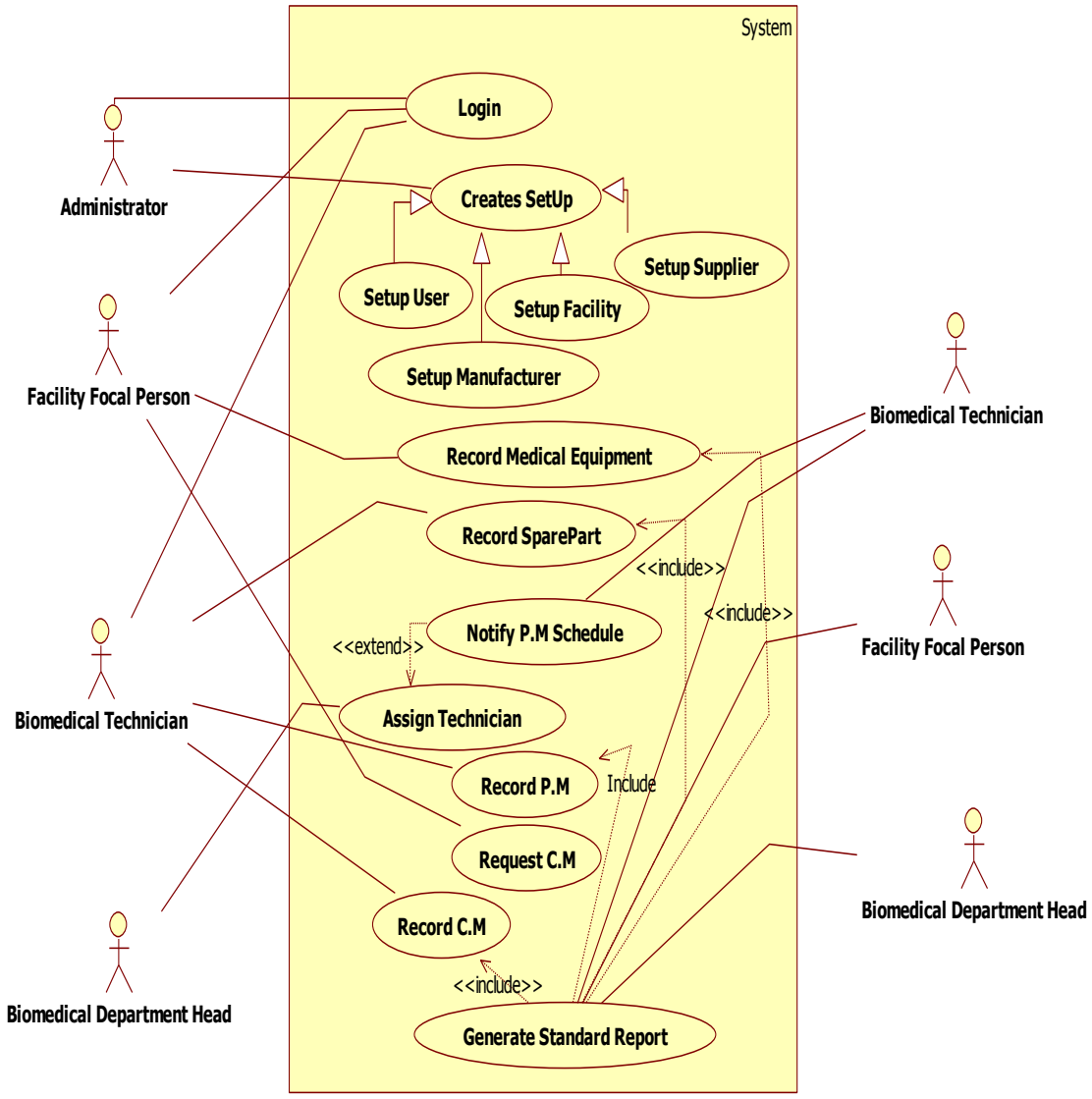


Figure 4.1: System Use Case Diagram for Medical Equipment Information Management

4.1.2. Use Case Narration and Activity Diagram Presentation

Use Case ID:	**UC-01**
Use Case Title	Login
Use case Description	This use case describes the user login process to enter into the system and use other functionalities.
Primary Actors	Biomedical technician, Biomedical department head, Facility focal person, Administrator.
Trigger	User tries to access the medical equipment information system
Pre-Conditions	The user has authorized user name and password.
Post-Conditions	The system displays system main menu screen.
Main scenario	6.User opens the medical equipment information system screen; 7.The user clicks login button; 8.The system displays login form; 9. The user enters ordinary user name and password and presses login button; 10. The system displays main menu screen;
Alternative scenario	4.1 If the user enters administrator name and password; 4.1.a. The system displays Administrator screen;
Frequency of Use	More than 88 per month
Business Rule	The system allows only two trials to access the system. If the user fails to enter valid Username or password, the system locks for one minute automatically.

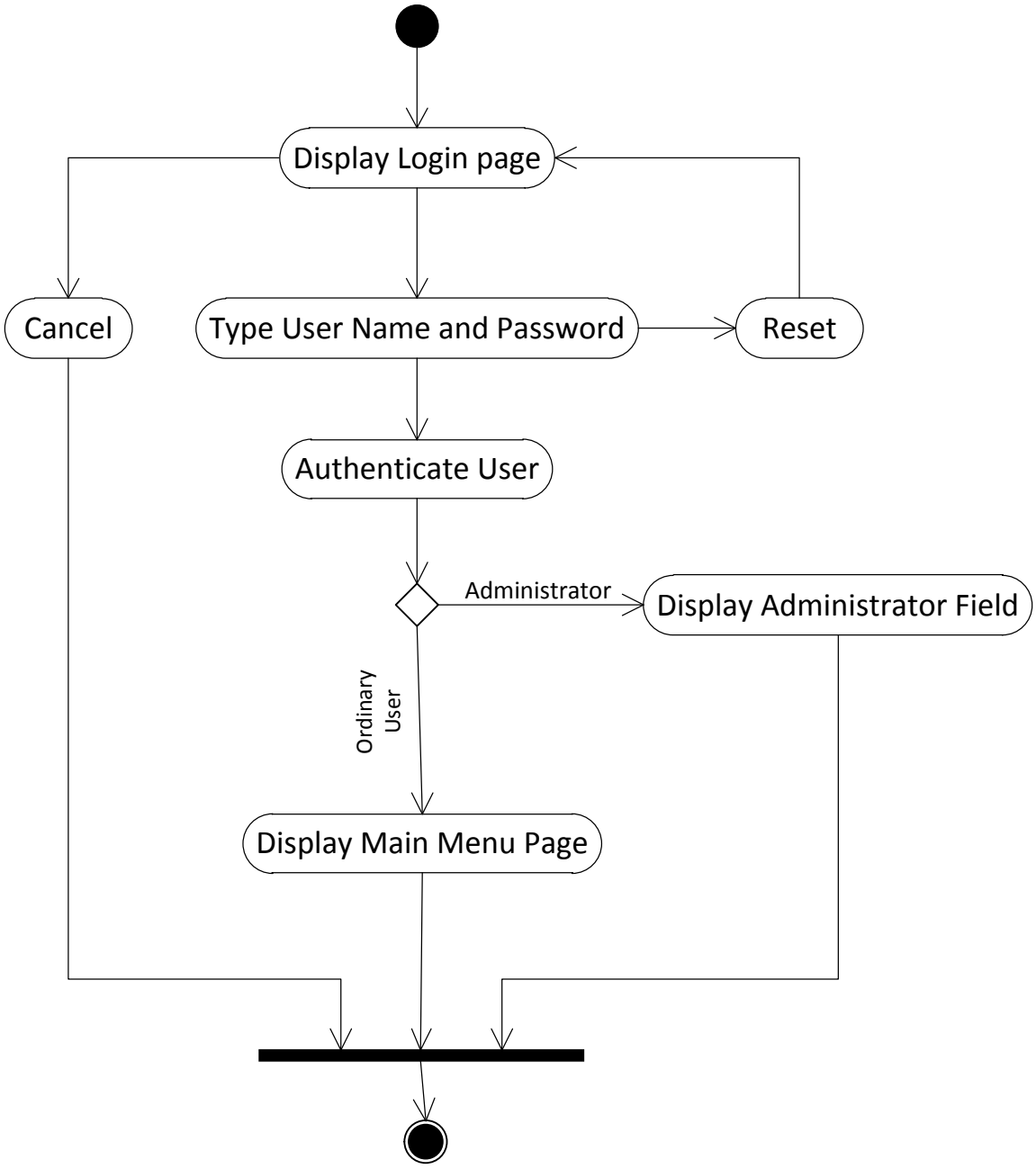


Figure 4.2: The activity diagram for login process

Use Case ID:	**UC-02**
Use Case Title	Create Setup
Use case Description	This use case describes the process of creating setups such as organizational setups.
Primary Actor	System Administrator
Trigger	The administrator intends to create user setup.
Pre-Conditions	The administrator logs into system administrator account
Post-Conditions	The system setup User/ Facility / Department / Supplier / Manufacturer
Main scenario	1. The system displays administrator screen with sub menu 2. The administrator selects User setup option 3. The system displays user setup form 4. The administrator enters the new user information and clicks save button 5. The system setups new user account
Alternative scenario	2.1 If the administrator selects facility Set up option 3.a. The system displays facility setup form 4.a. The administrator enters facility information and clicks save button 5.a. The system create new organizational set up 2.2 If the administrator selects department Set up option 3.b. The system displays department setup form 4.b. The administrator enters department information and clicks save button 5.b. The system creates new department set up 2.3 If the administrator selects supplier Set up option 3.c. The system displays supplier setup form 4.c. The administrator enters supplier information and clicks save button; 5.c. The system creates new supplier set up; 2.4 If the administrator selects manufacturer Set up option;

	3.d. The system displays manufacturer setup form; 4.d. The administrator enters manufacturer information and clicks save button; 5.d. The system creates new manufacturer set up ;
	4.1. If the administrator clicks cancel button ; 5.a. The system returns to the main menu ; 4.2. If the administrator clicks reset button ; 5.b. The system clears the input boxes;
Frequency of Use	4 per month
Business Rule	

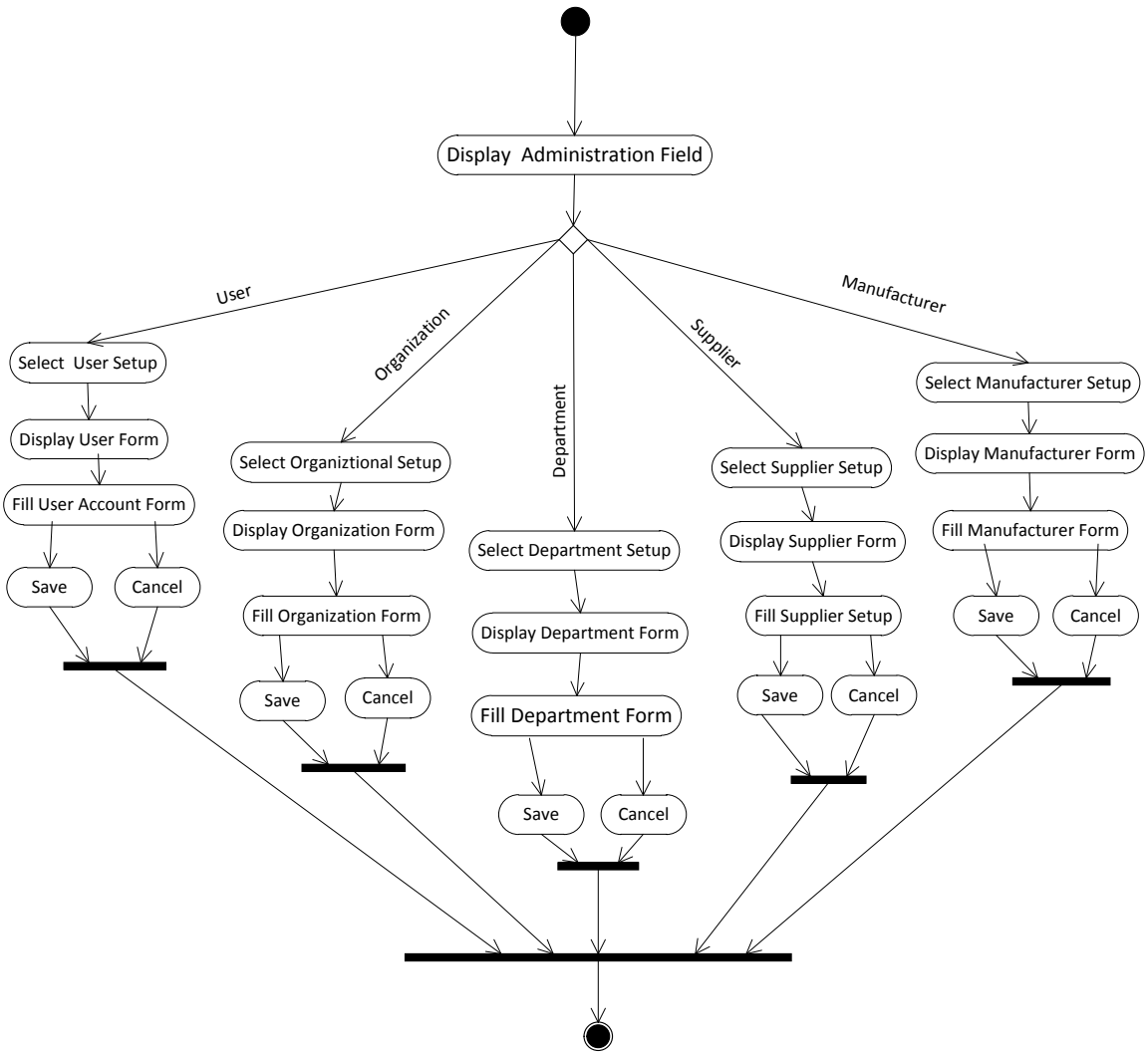


Figure4.3: Activity Diagram for Administration process of MEIMS

Use Case ID:	**UC-03**
Use Case Title	Register medical equipment
Use case Description	This use case describes the process of registering electronic medical equipment information.
Primary Actor	Facility focal person
Trigger	The focal person attempts to register medical equipment by selecting the medical equipment option from system main menu
Pre-Conditions	The user is logged in to the system
Post-Conditions	Medical equipment information is recorded in the system database. The equipment is assigned a unique ID.
Main scenario	11. The user selects medical equipment recording menu option; 12. The system displays medical equipment recording form; (Figure 4.21) 13. The user fills the form with equipment information; 14. The user clicks submit button; 15. The system saves the equipment information on the system database and make the form ready for the next record;
Alternative scenario	4.1. If the user clicks on cancel button; 5.a. The system return to the main menu; 4.2. If the user clicks on reset button; 5.b. The system clear the input box;
Frequency of Use	About 40 per month
Business Rule	

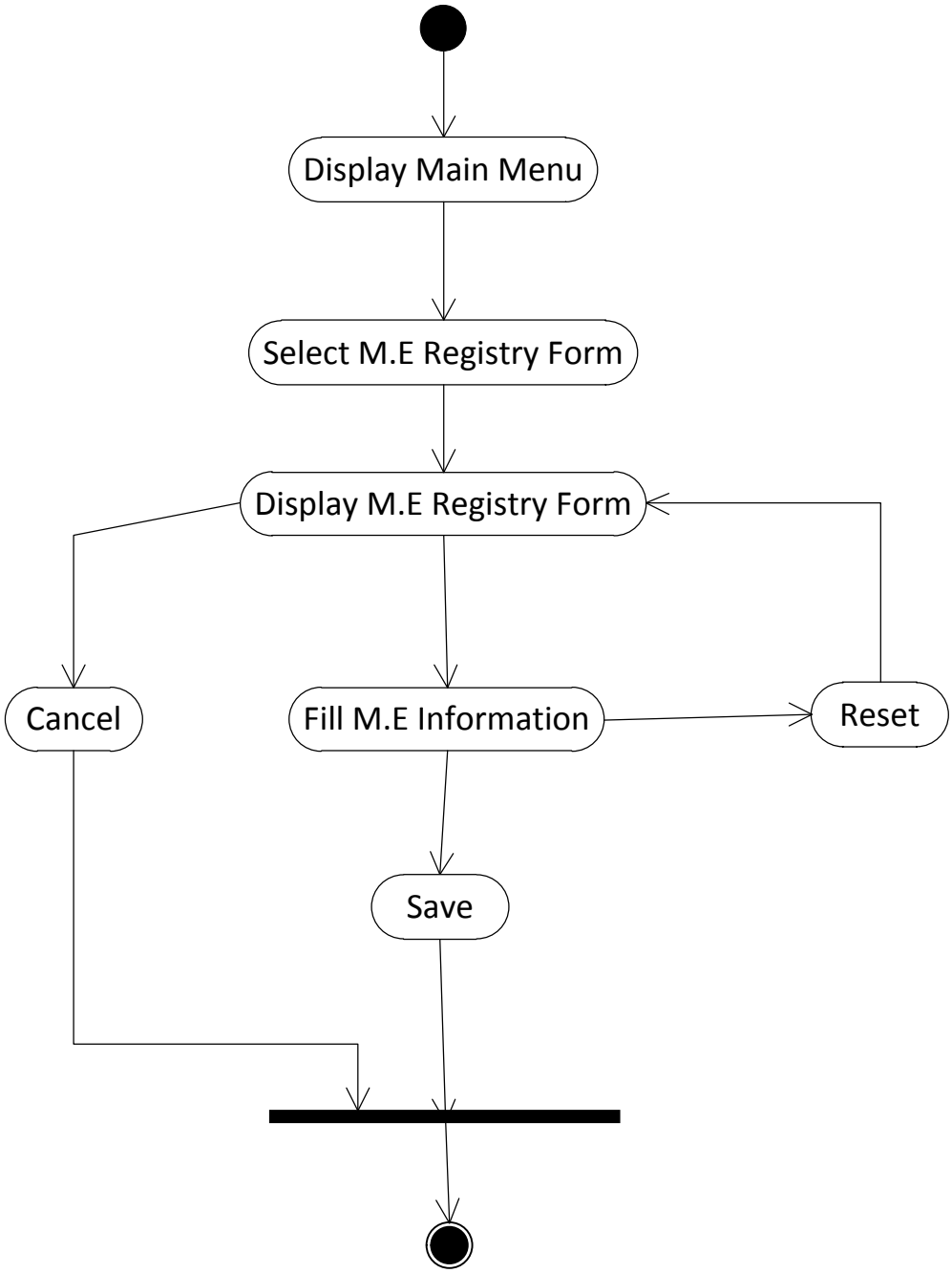


Figure 4.4: Activity diagram for medical equipment registering process

Use Case ID:	**UC-04**
Use Case Title	Register Spare parts
Use case Description	This use case describes the process of recording electronic spare part information.
Primary Actor	Biomedical Technician.
Trigger	The technician attempts to register spare part by selecting the spare part recording option from system main menu.
Pre-Conditions	The user is logged in to the system.
Post-Conditions	The spare part information is recorded in the system database. The spare part is assigned a unique ID.
Main scenario	1. The user selects spare part recording menu option; 2. The system displays spare part recording form(Figure4.26); 3. The user fills the form with spare part information; 4. The user clicks submit button; 5. The system save spare part information in the system database and makes the form ready for the next record;
Alternative scenario	4.1. If the user clicks on cancel button; 5.a. The system return to the main menu; 4.2. If the user clicks on reset button; 5.b. The system clear the input box;
Frequency of Use	About 30 per month
Business Rule	

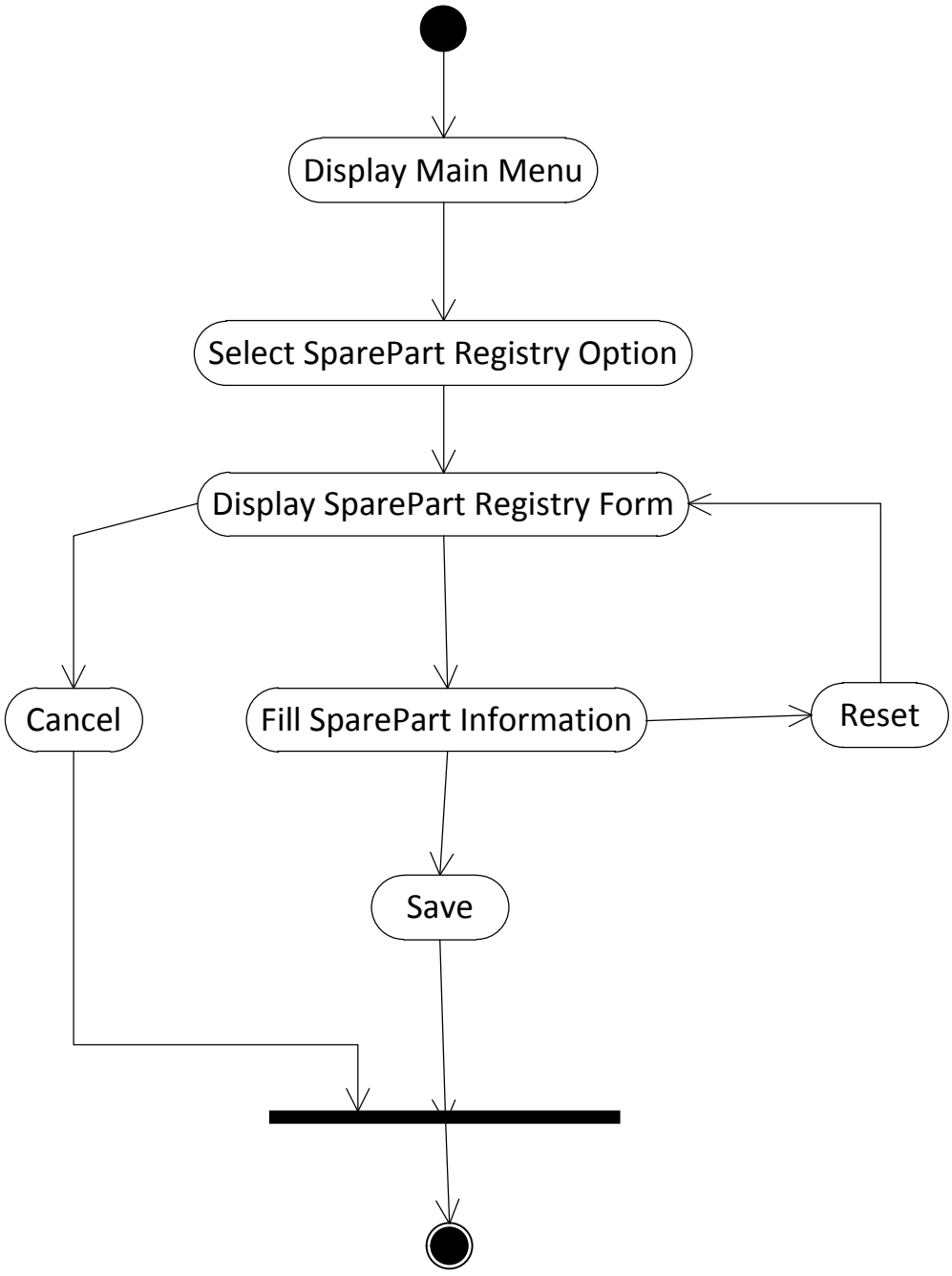


Figure 4.5: Activity diagram for spare part registration process

Use Case ID:	**UC-05**
Use Case Title	Produce preventive maintenance schedule.
Use case Description	This use case describes the process of producing electronic preventive maintenance schedule.
Primary Actor	The MEIMS
Trigger	When time is due for preventive maintenance.
Pre-Conditions	The frequency of preventive maintenance schedule of each equipment is recoded on the equipment database registration.
Post-Conditions	The information of preventive maintenance schedule will be displayed.
Main scenario	1. The system checks time of preventive maintenance of equipment from the system database; 2. The system displays preventive maintenance notification message;
Alternative scenario	
Frequency of Use	About 20 per month
Business Rule	

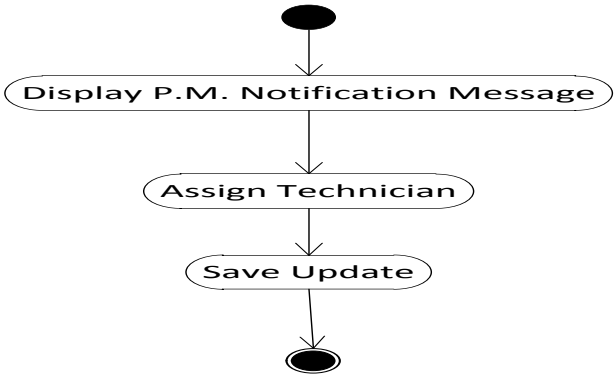


Figure 4.6: Activity Diagram For Preventive Maintenance Notification Message

Use Case ID:	**UC-06**
Use Case Title	Assign Technician.
Use case Description	This use case describes the process of assigning technician for preventive maintenance work.
Primary Actor	Biomedical department head.
Trigger	When the system displays Preventive maintenance schedule.
Pre-Conditions	The frequency of preventive maintenance schedule of each equipment is recoded on the equipment database registration.
Post-Conditions	The system save technician assigned for the specific preventive maintenance.
Main scenario	1.The user requests detail of the preventive maintenance schedule; 2.The system displays the list of equipment need preventive maintenance with their specified location; 3.The user fills the name of the responsible technician and clicks on save button; 4.The system saves the responsible technician name in the database;
Alternative scenario	No
Frequency of Use	About 20 per month
Business Rule	

Use Case ID:	**UC-07**
Use Case Title	Record preventive maintenance information
Use case Description	This use case describes the process of recording electronic preventive maintenance.
Primary Actor	Biomedical technician
Trigger	The technician attempts to record preventive Maintenance by selecting the preventive maintenance recording option from system main menu.
Pre-Conditions	The user is logged in to the system.
Post-Conditions	The preventive maintenance record is saved in the system database.
Main scenario	1. The user selects preventive maintenance recording form options; 2. The system displays preventive maintenance record form; 3. The user selects the equipment and fills the preventive maintenance form and clicks on save button; 4. The system saves the record in the preventive maintenance database;
Alternative scenario	3.1. If the user clicks on cancel button; 4.a. The system return to the main menu; 3.2. If the user clicks on reset button; 4.b. The system clear the input box;
Frequency of Use	About 20 per month
Business Rule	No

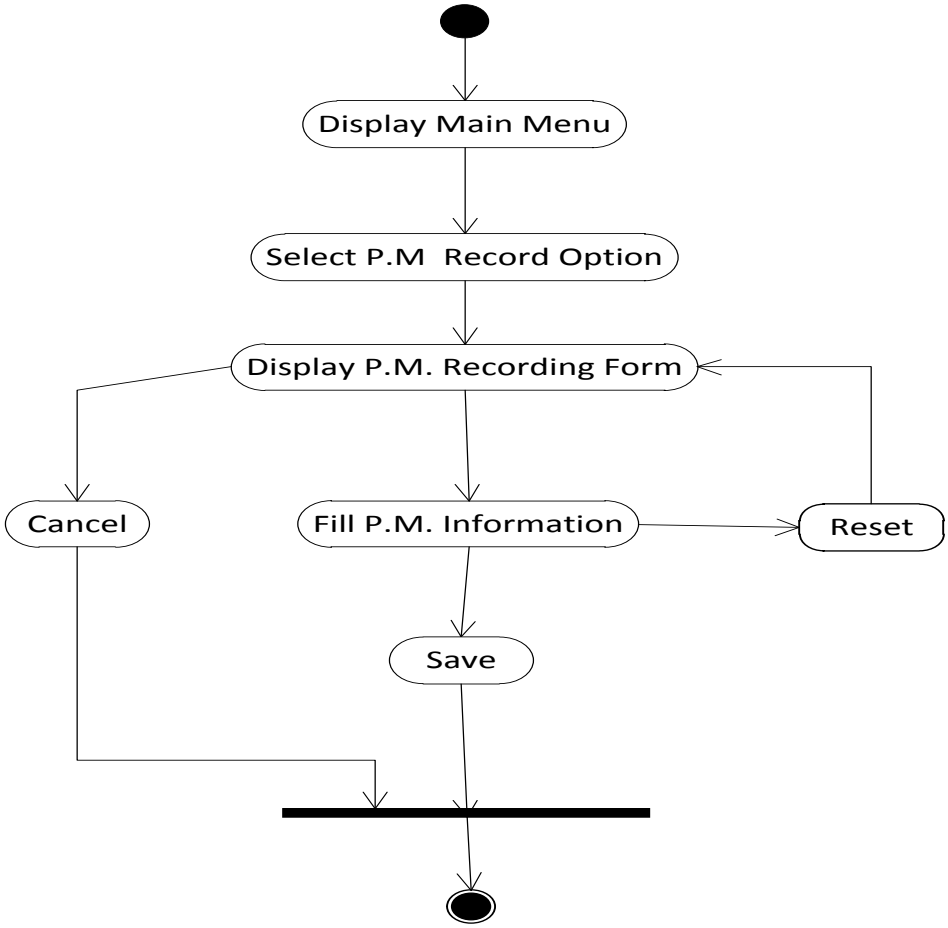


Figure 4.7: Activity Diagram for Preventive Maintenance Recording

Use Case ID:	**UC-08**
Use Case Title	Complete corrective maintenance work order
Use case Description	This use case describes the process completing electronic corrective maintenance work order.
Primary Actor	Facilities focal person
Trigger	The focal person attempts to fill corrective maintenance request form by selecting the work order option from system main menu.
Pre-Conditions	The user is logged in to the system.
Post-Conditions	The corrective maintenance work order is recorded in the system database.
Main Scenario	1. The user selects corrective maintenance work order form(Figure4.24); 2. The system displays maintenance work order form; 3. The user fills the work order requests form and click on save button; 4. The system saves the work order in to the system database and display work order message;
Alternative scenario	3.1. If the user clicks on cancel button; 4.a. The system return to the main menu; 3.2. If the user clicks on reset button; 4.b. The system clear the input box;
Frequency of Use	30 per month
Business Rule	

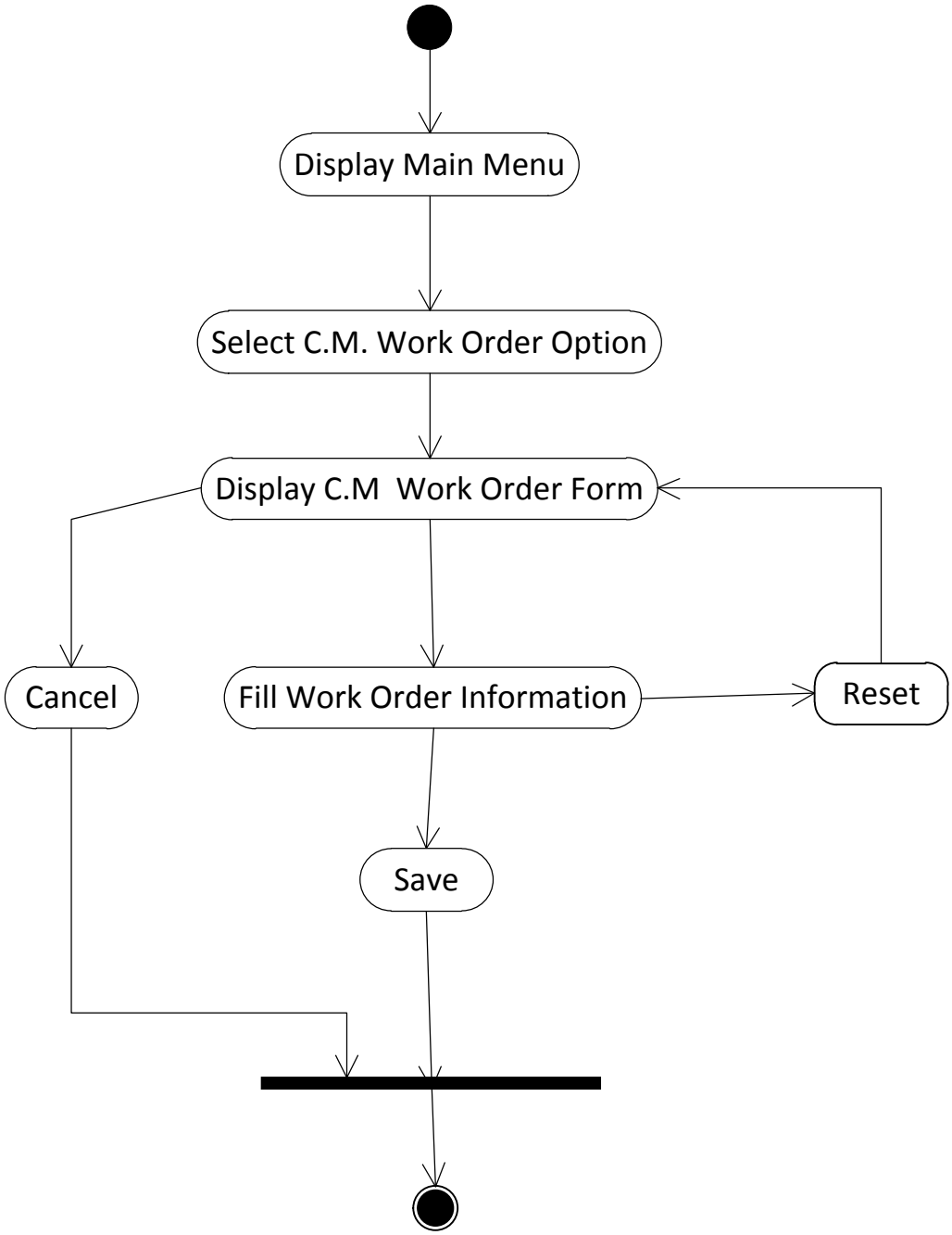


Figure 4.8: Activity Diagram For Corrective Maintenance Work Order

Use Case ID:	**UC-09**
Use Case Title	Record corrective maintenance information
Use case Description	This use case describes the process of recording electronic corrective maintenance.
Primary Actor	Biomedical Technician
Trigger	The biomedical technician attempts to record corrective maintenance by selecting the corrective maintenance recording option from system main menu.
Pre-Conditions	The user is logged in to the system .
Post-Conditions	The corrective maintenance record is saved in the system database.
Main Scenario	1. The user selects corrective maintenance recording form options; 2. The system displays corrective maintenance record form; 3. The user selects the equipment and fills the corrective maintenance form and clicks on save button; 4. The system saves the record in the corrective maintenance database; 5. The user click on print button; 6. The system print out the corrective maintenance recorded;
Alternative scenario	3.1. If the user clicks on cancel button; 4.a. The system return to the main menu; 3.2. If the user clicks on reset button; 4.b. The system clear the input box;
Frequency of Use	30 per month
Business Rule	

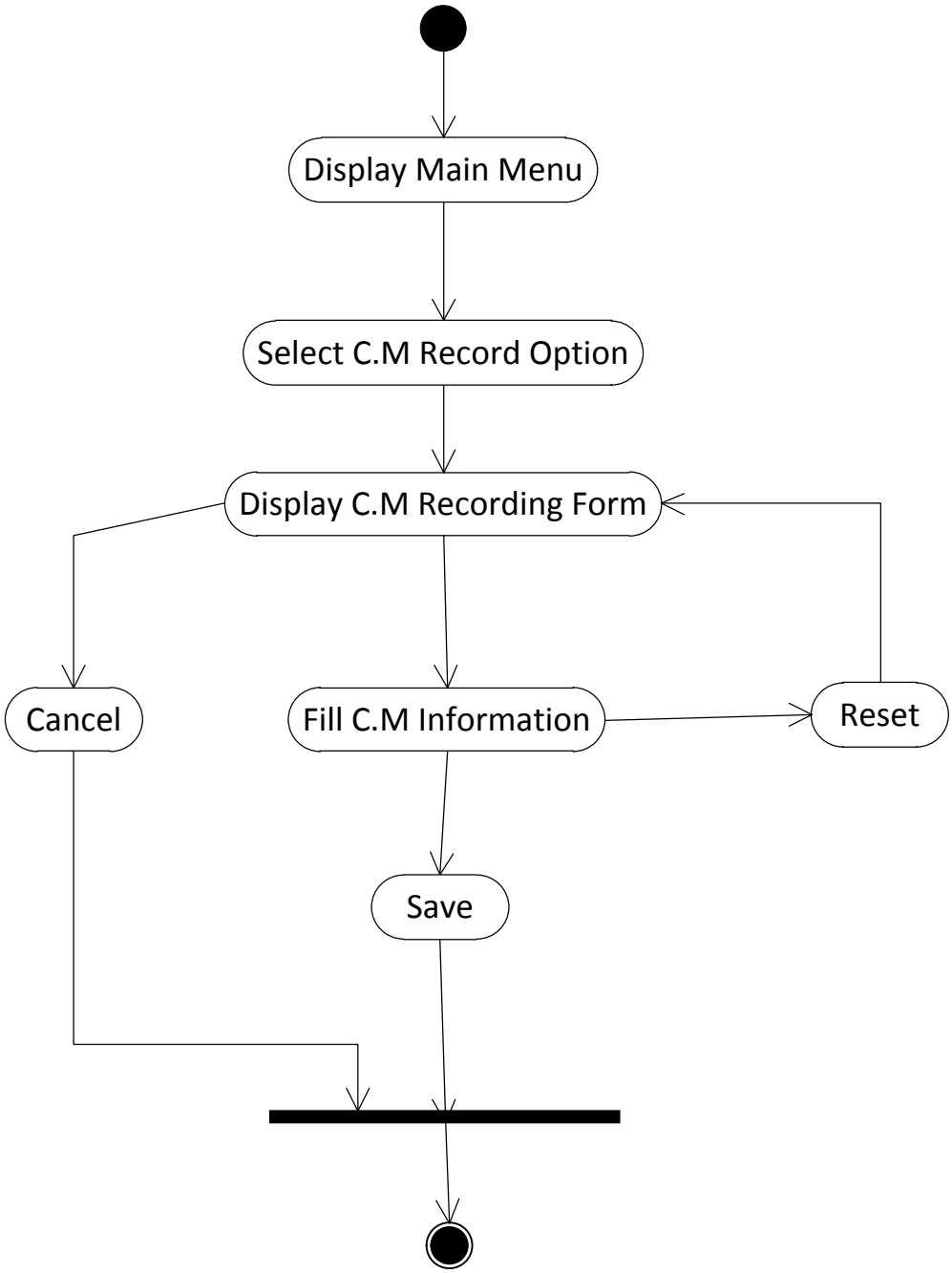


Figure 4.9: Activity Diagram For Corrective Maintenance information Recording Process

Use Case ID:	**UC-10**
Use Case Title	Generate standard report
Use case Description	This use case describes the process of producing an electronic standard report.
Primary Actor	Biomedical Department head, Facility focal person, Biomedical technician, Administrator
Trigger	The user attempts to generate report by selecting the report option from system main menu.
Pre-Conditions	The user is logged in to the system.
Post-Conditions	The system generate reports
Main Scenario	1. The user selects report menu; 2. The system displays report option for the user; 3. The user selects option of the report to be generated and clicks on generate button; 4. The system generates report from the database on the selected option;
Alternative scenario	3.1. If the user clicks on export button; 4.a. The system export the report; 3.2. If the user clicks on print button; 4.b. The system print out the report; 3.3. If the user clicks on cancel button; 4.c. The system return to the main menu;
Frequency of Use	Minimum 1 per month
Business Rule	

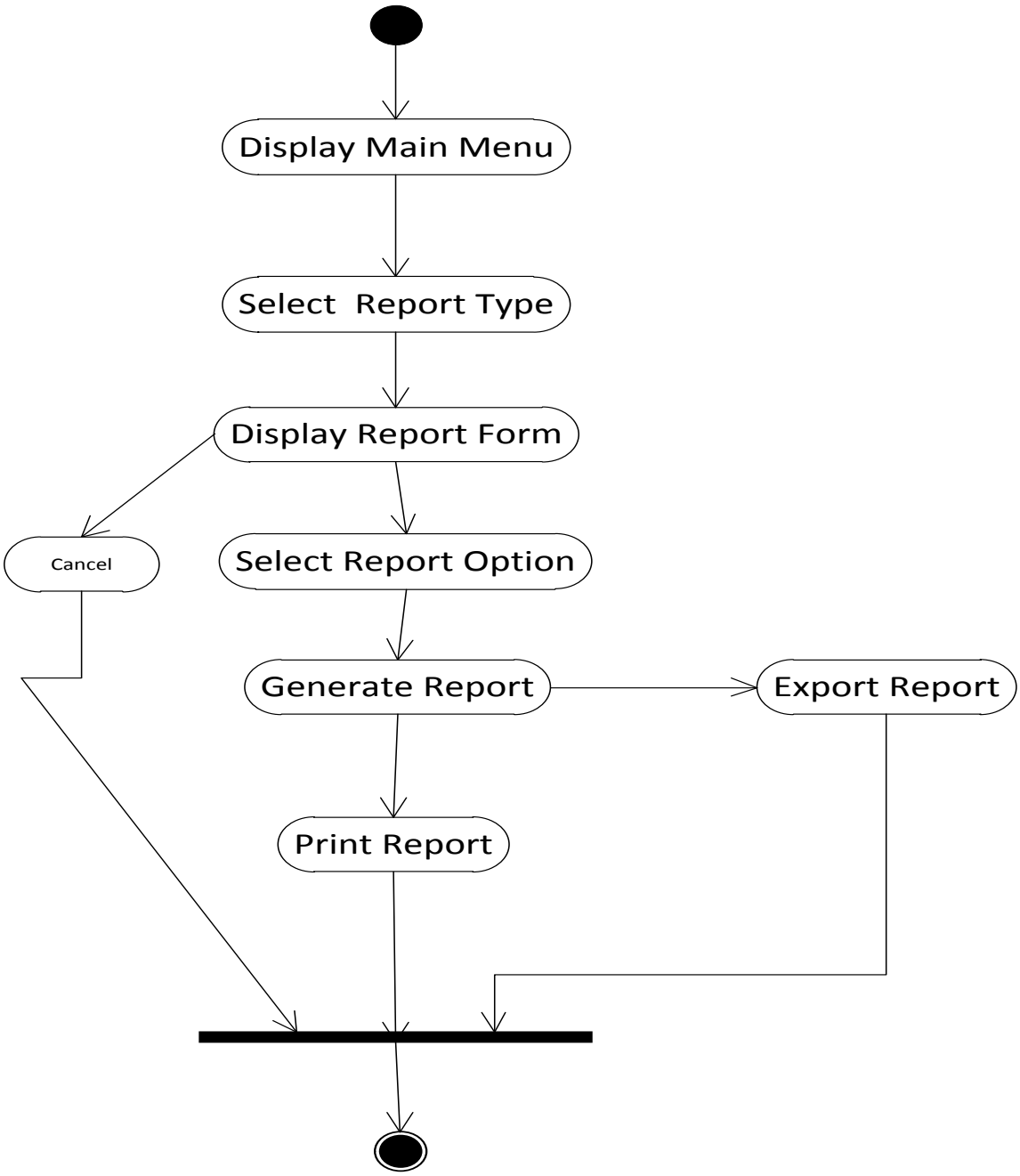


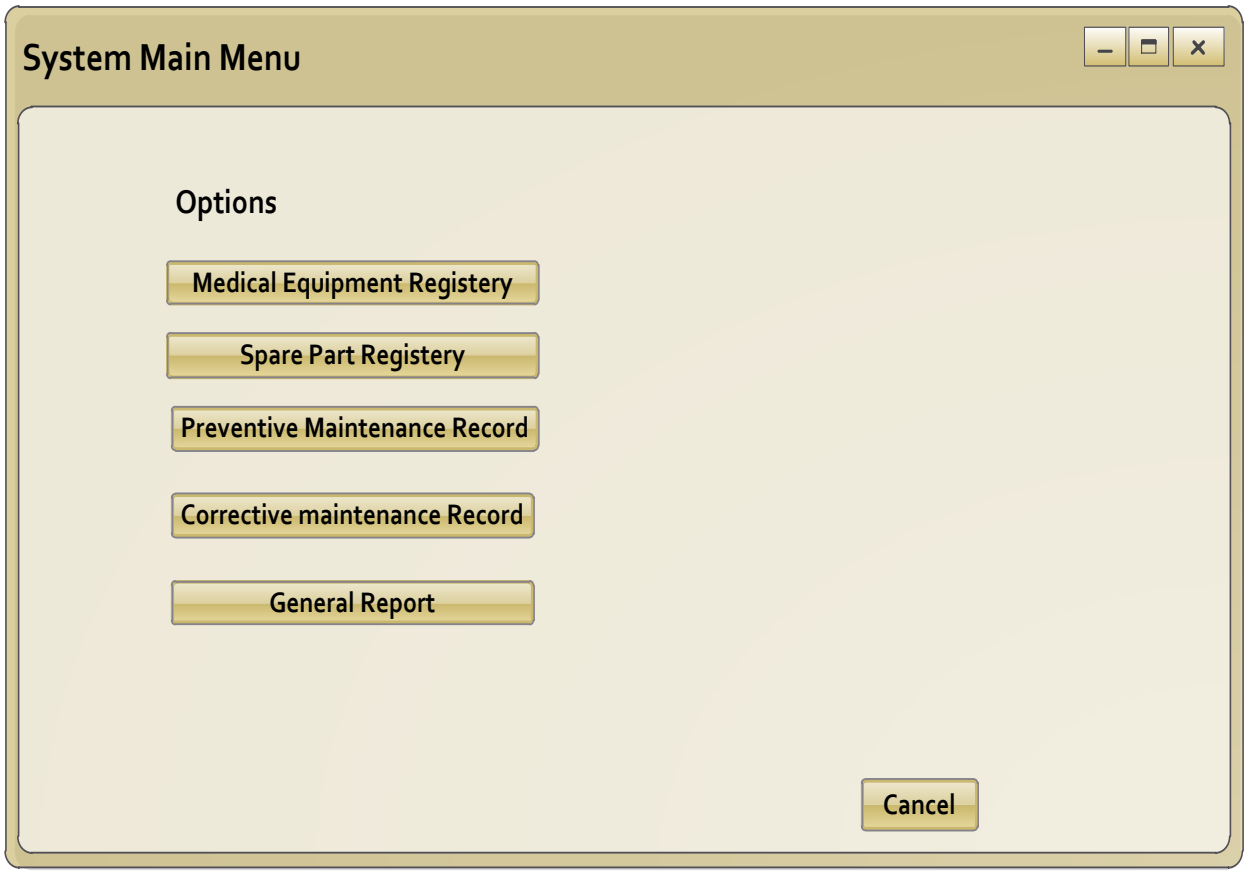
Figure 4.10: Activity Diagram for generating report

4.1.3. User Interface Prototype Presentation

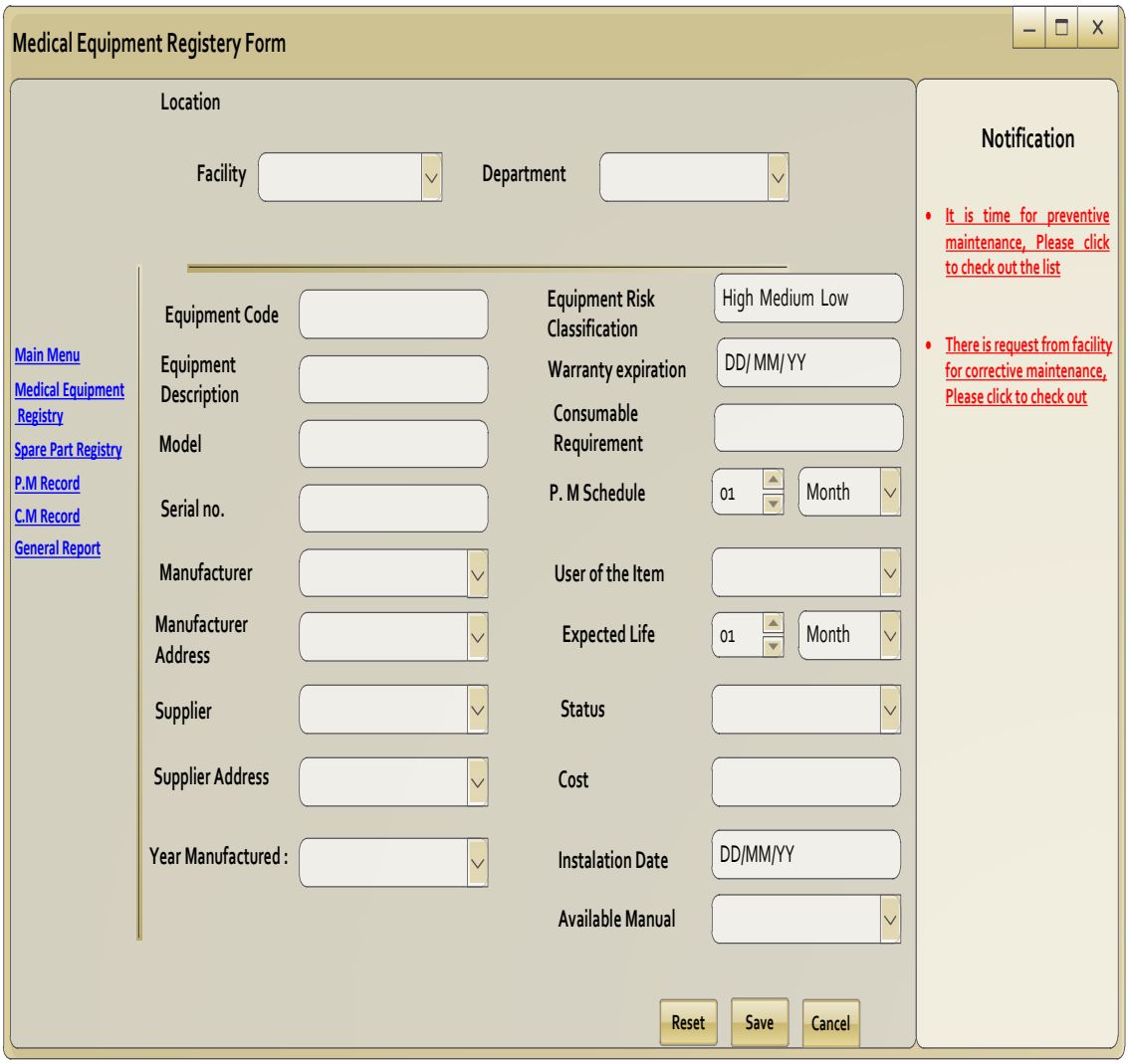
User interface prototype is a model used to simulate the system user interface at an early stage of the system design. It can be developed using hand drawing or CASE tool like Visio. It helps to make the end user to test the system at an early stage and identify the gaps in very low cost and time. It also helps to communicate ideas between designer, developer, users and stakeholders. The following user interface prototype is developed using Visio presents the new system.

User Interface Prototype Id: UIP-01

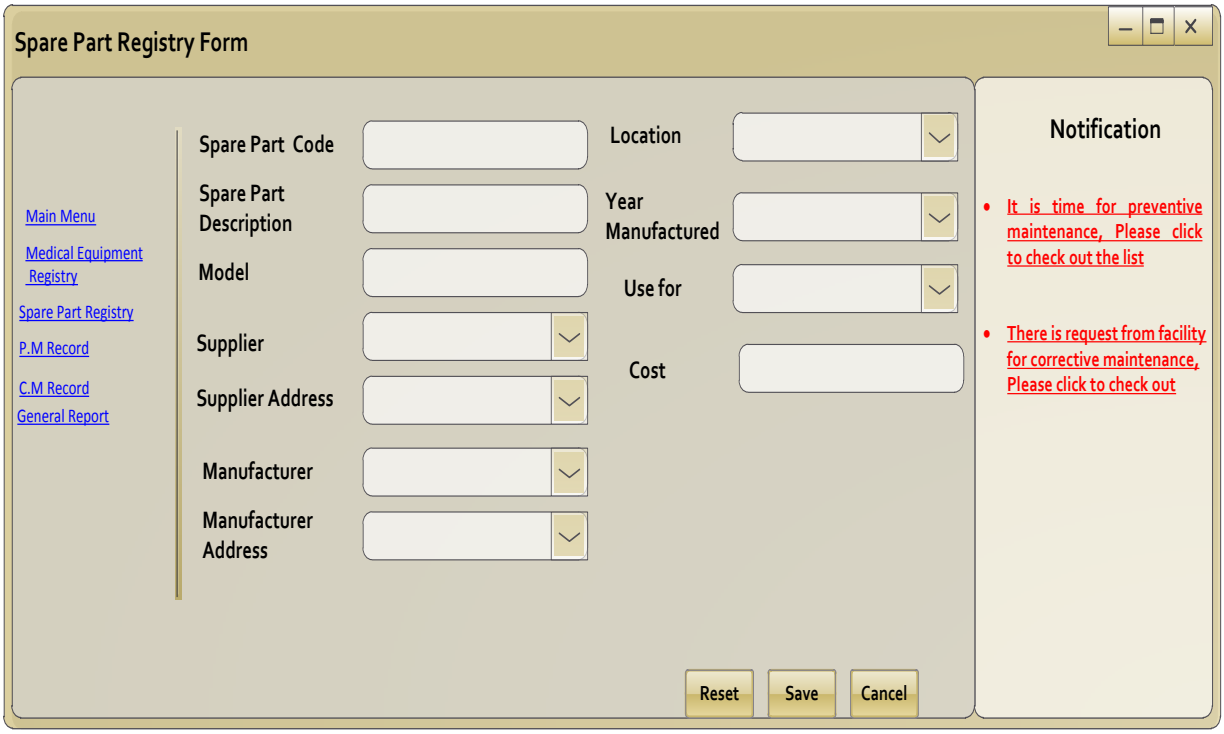
User Interface Prototype Id: UIP -02



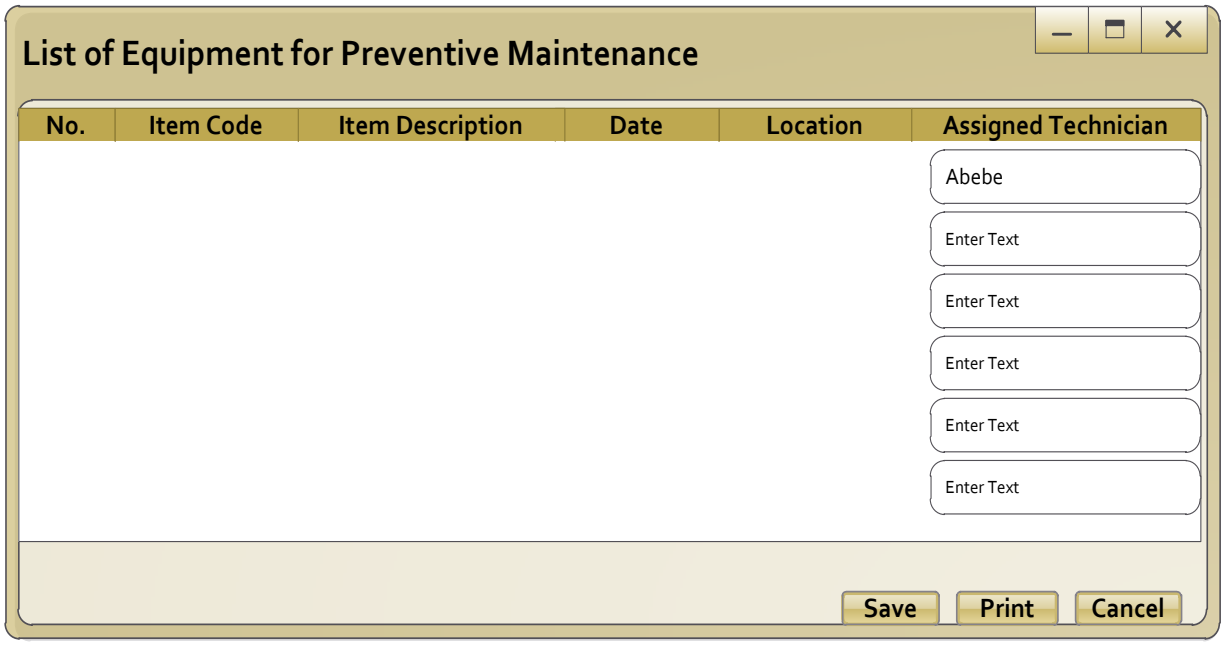
User Interface Prototype Id: UIP 0.3



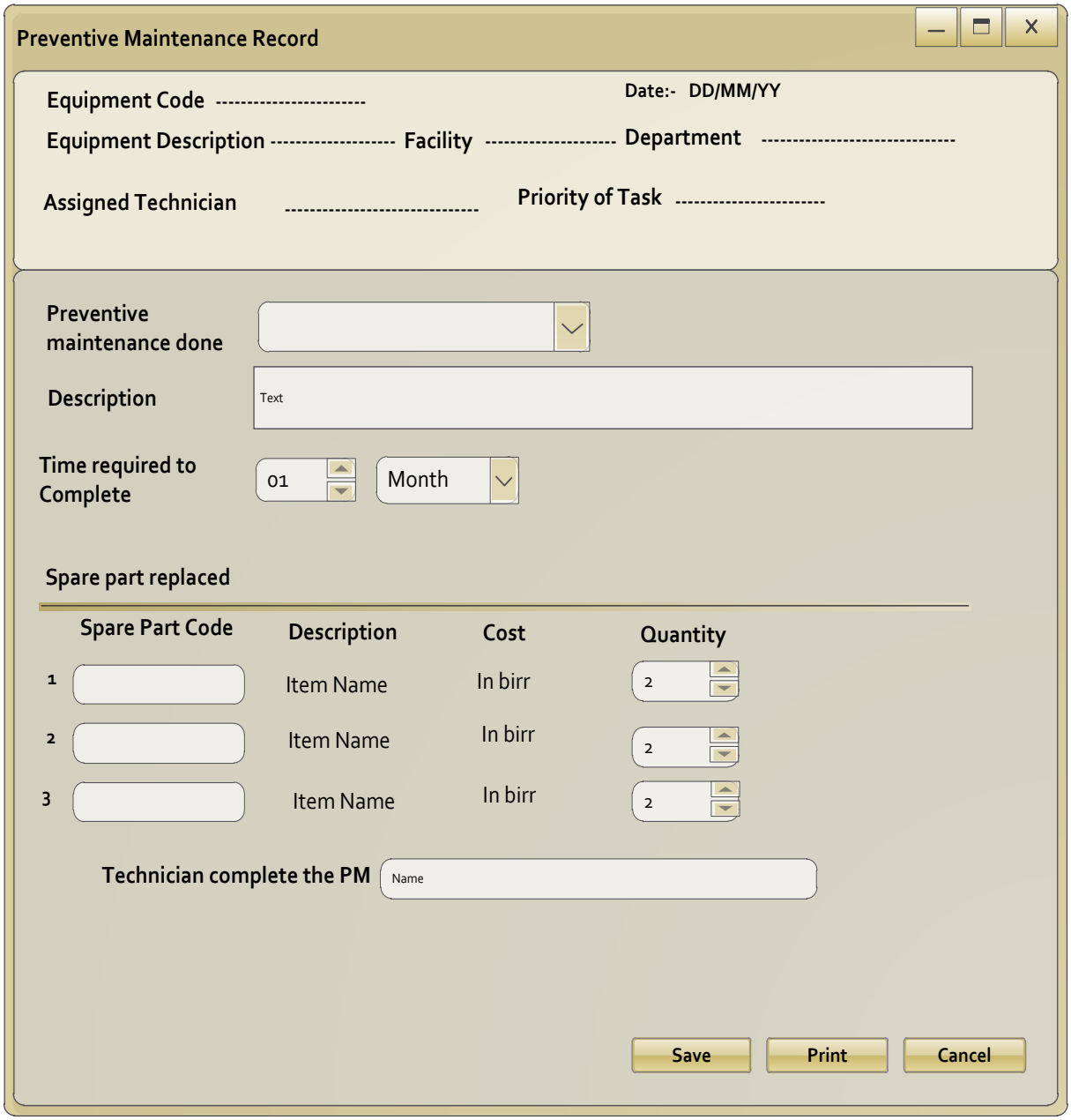
User Interface Prototype Id:UIP-04



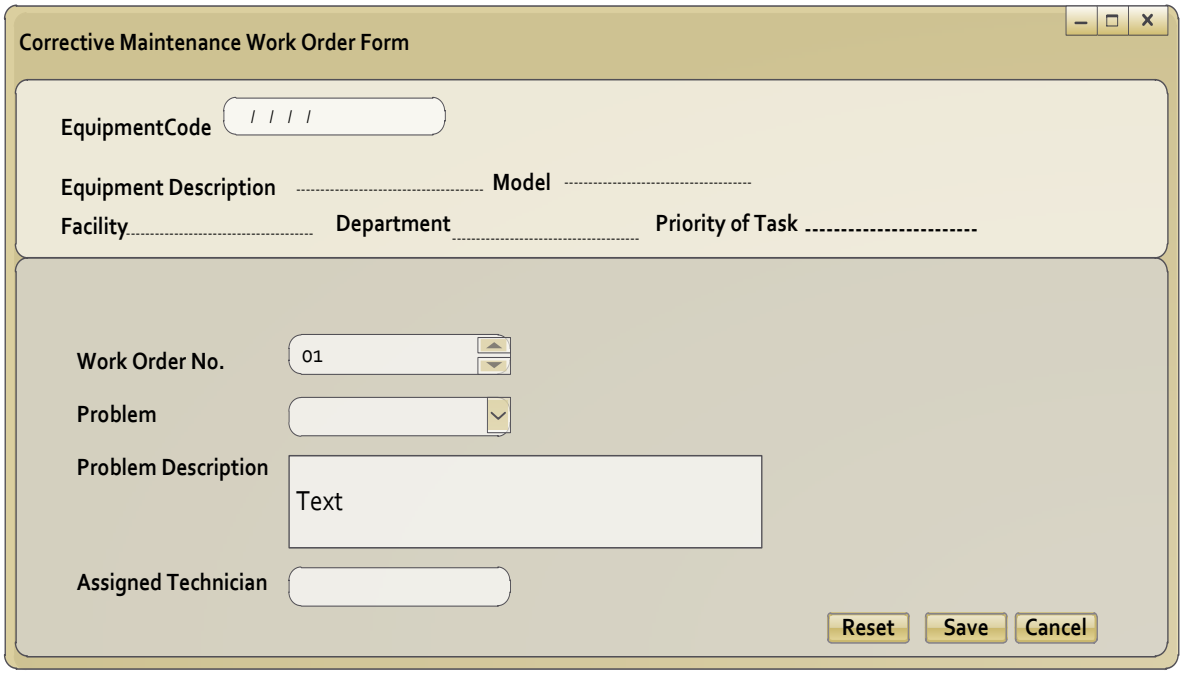
User Interface Prototype Id:UIP-05



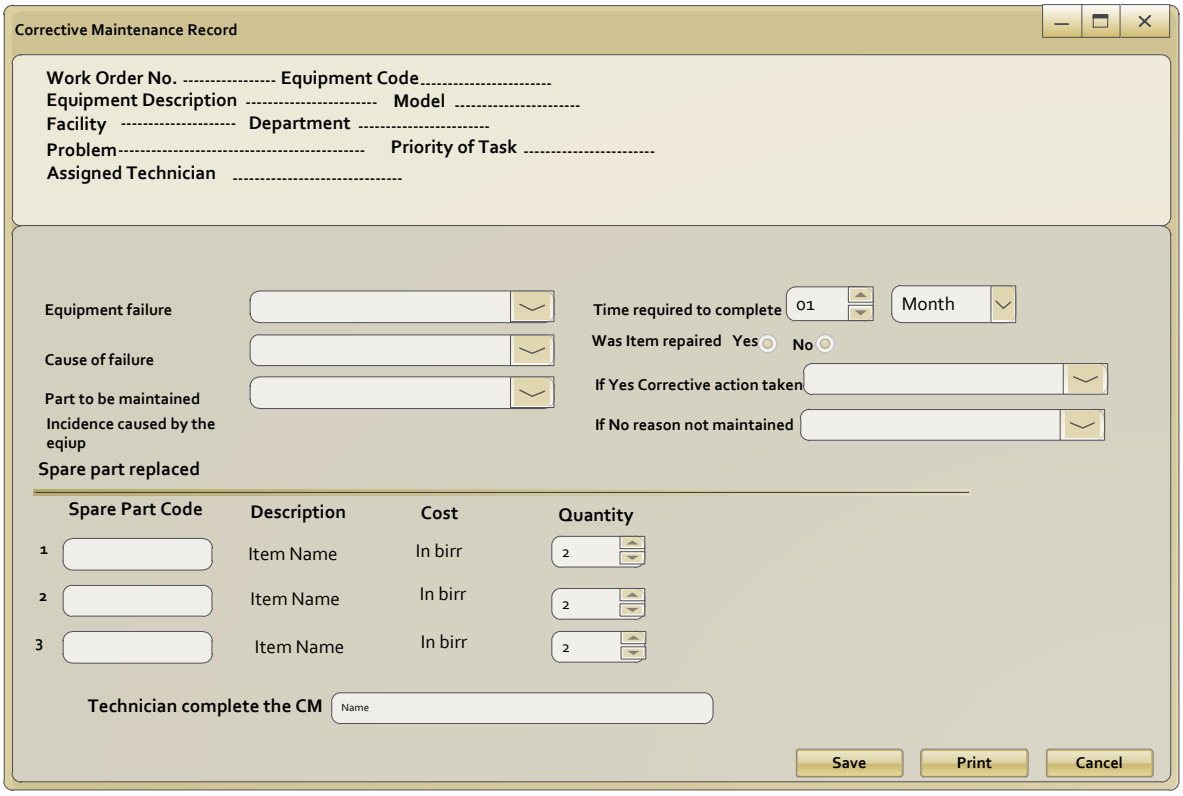
User Interface Prototype Id:UIP-06



User Interface Prototype Id:UIP-07

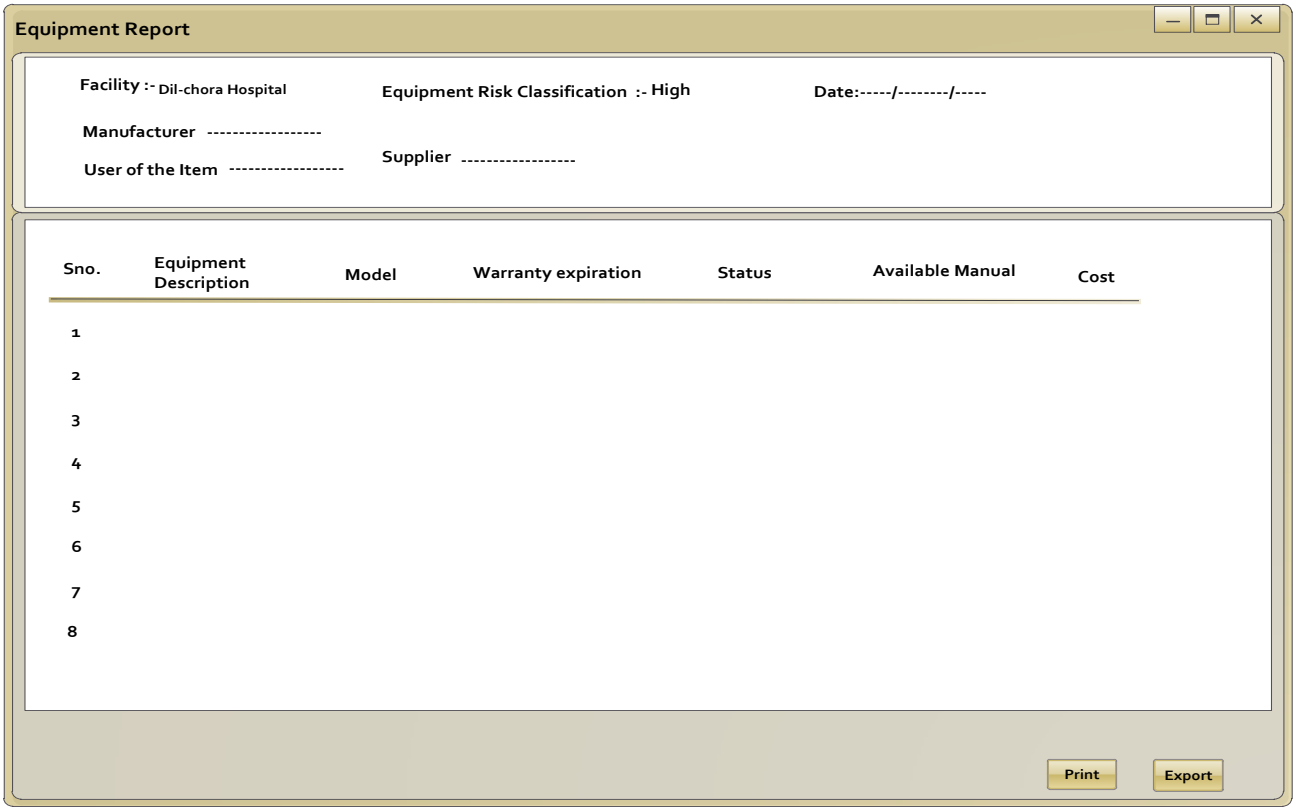


User Interface Prototype Id: UIP-08

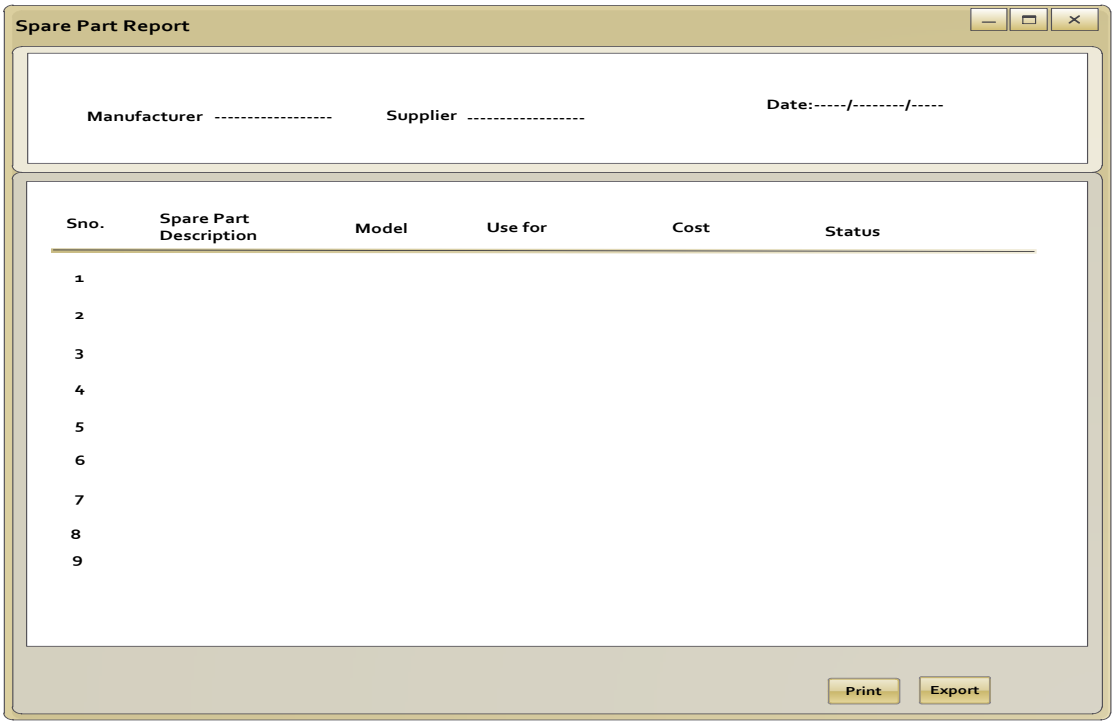


User Interface Prototype Id:UIP-09

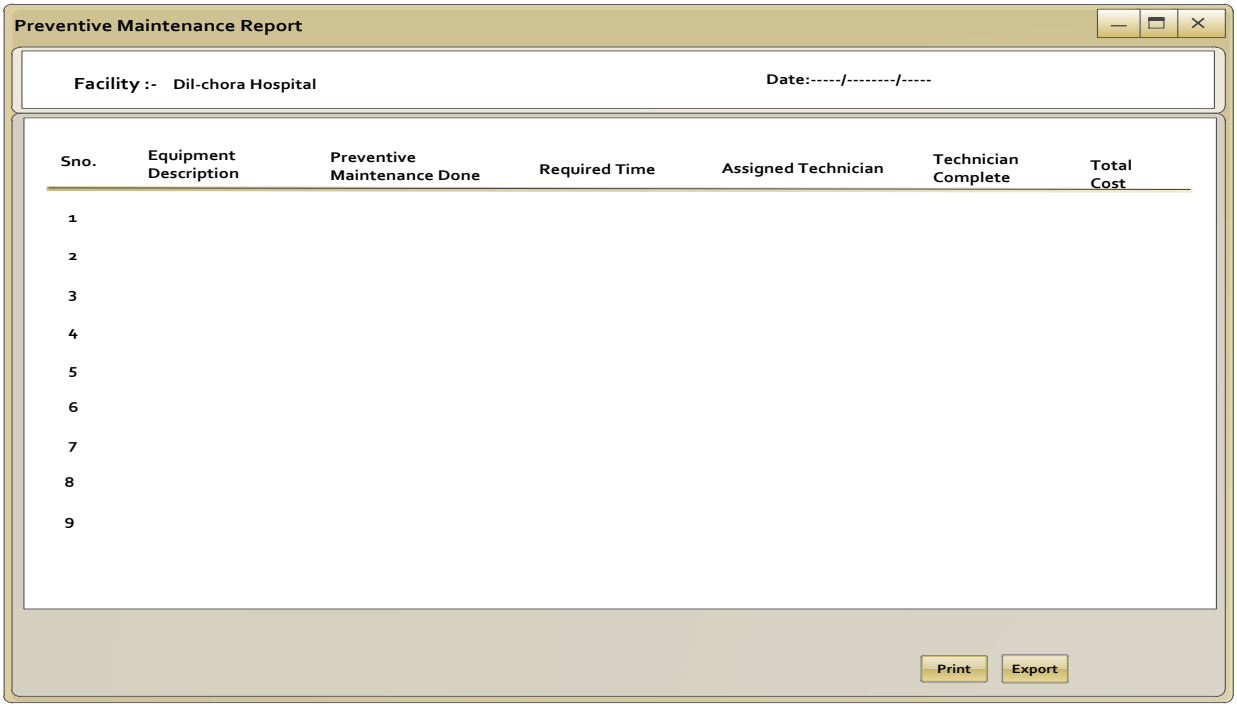
User Interface Prototype Id:UIP-10



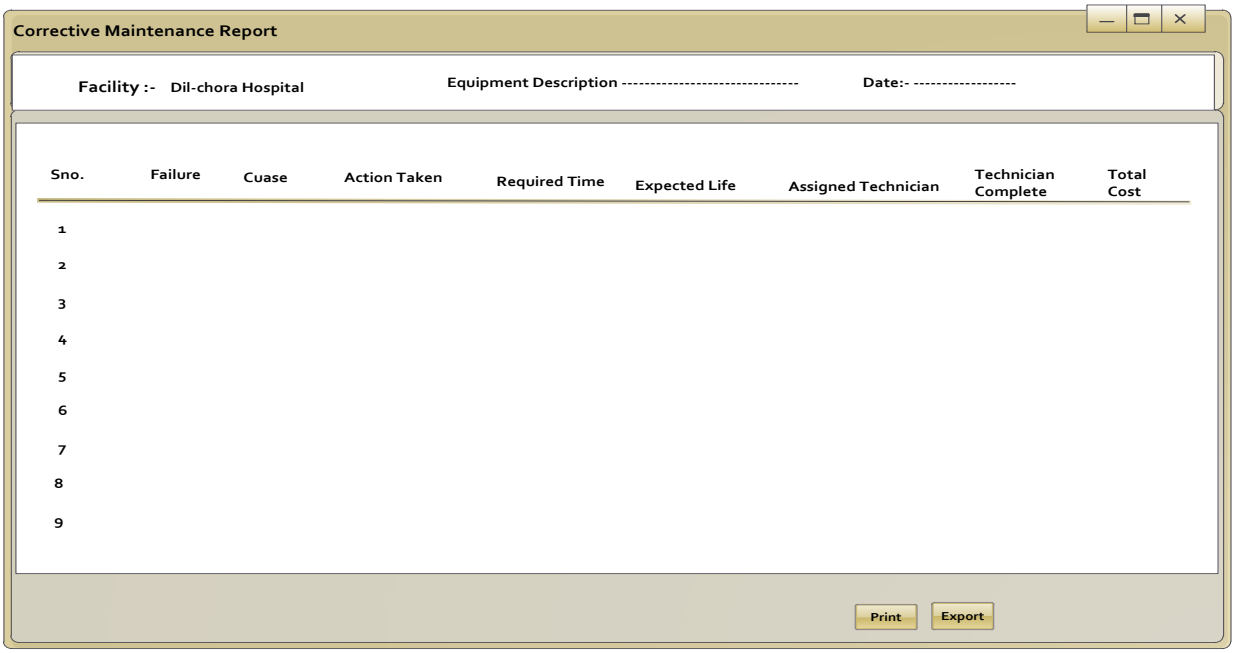
User Interface Prototype Id:UIP-11



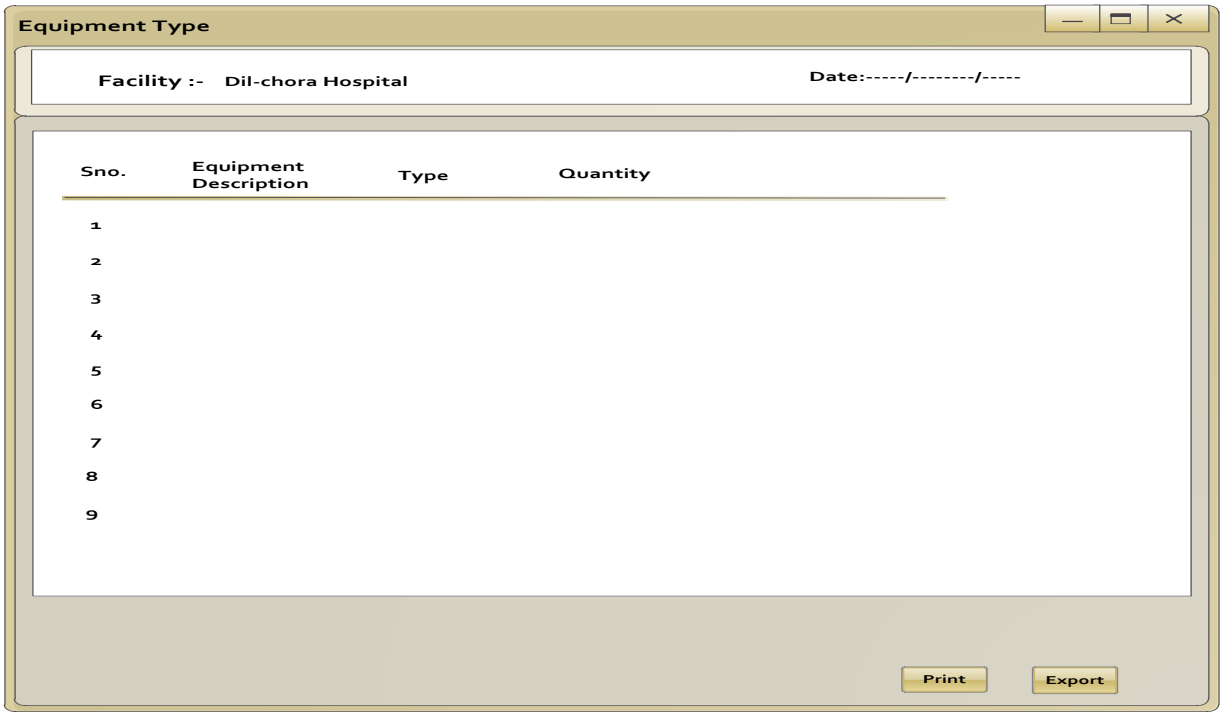
User Interface Prototype Id:UIP-12



User Interface Prototype Id:UIP-13



User Interface Prototype Id:UIP-14



4.2. System Design Model

The system design models presented using class diagram and Sequence diagram

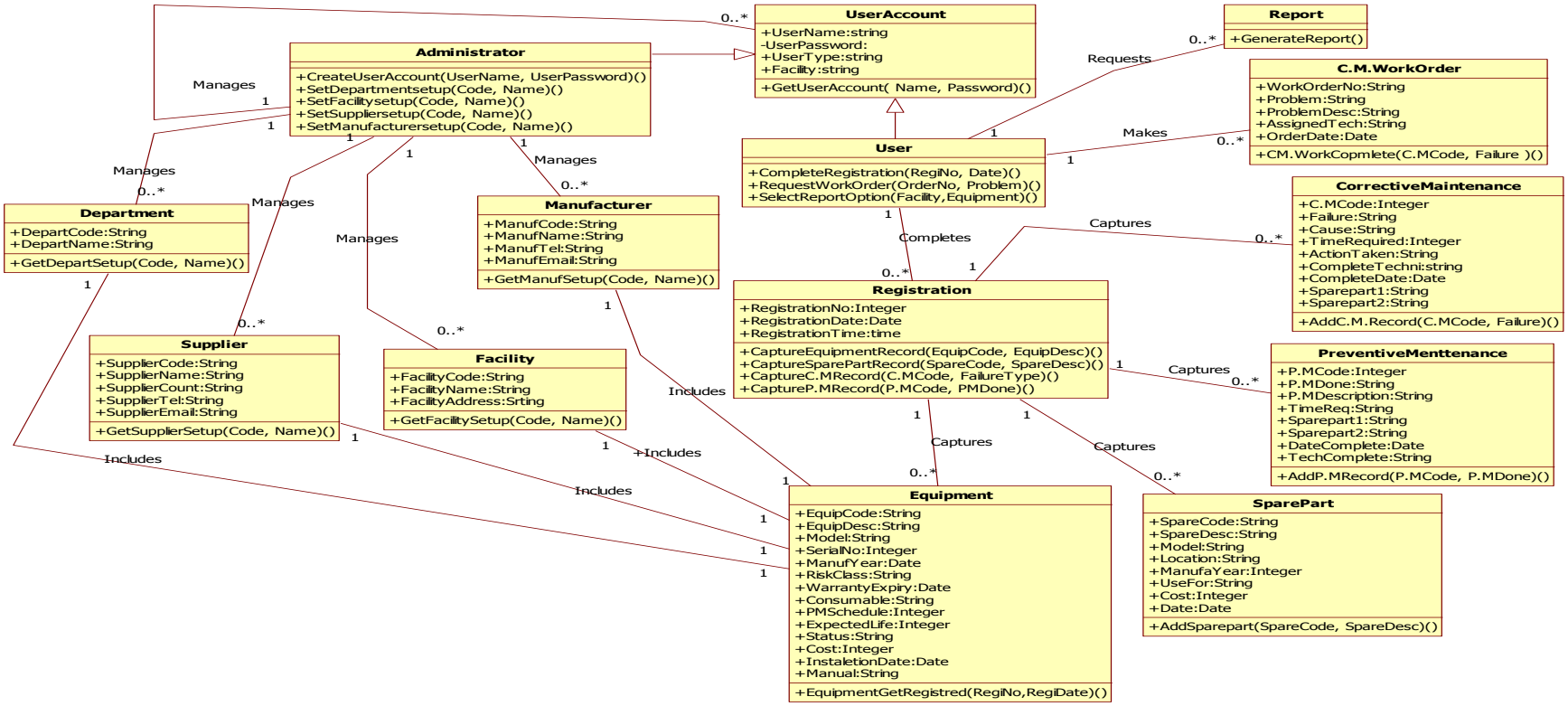


Figure 4.11: Class Diagram for Medical Equipment Information Management System

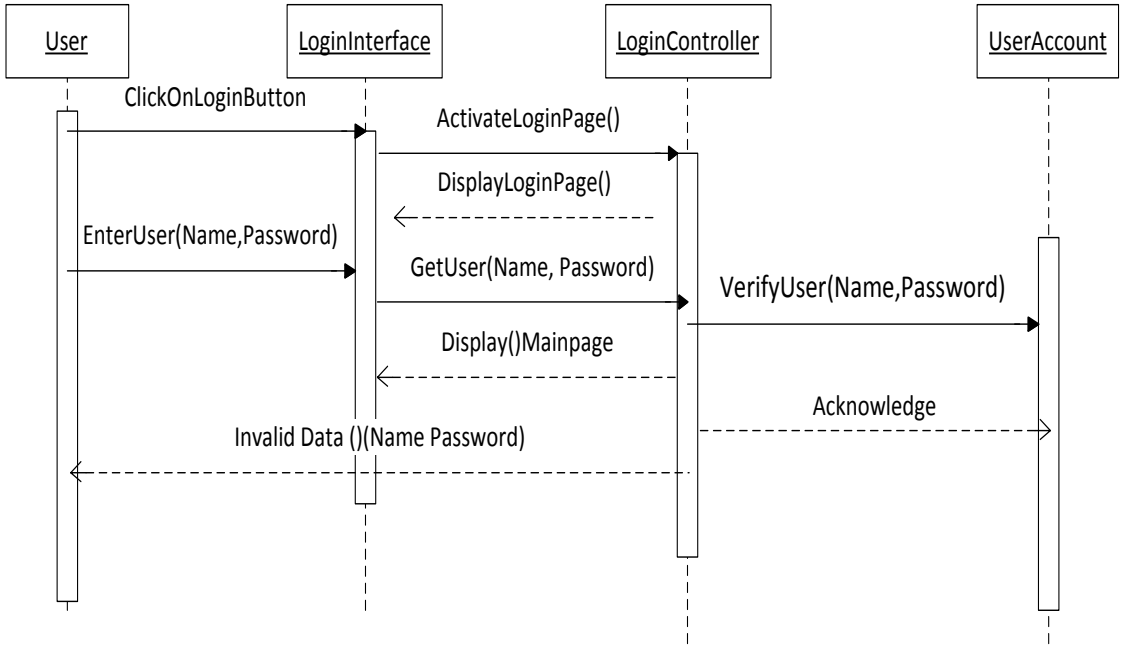


Figure 4.12: Sequence diagram for login process

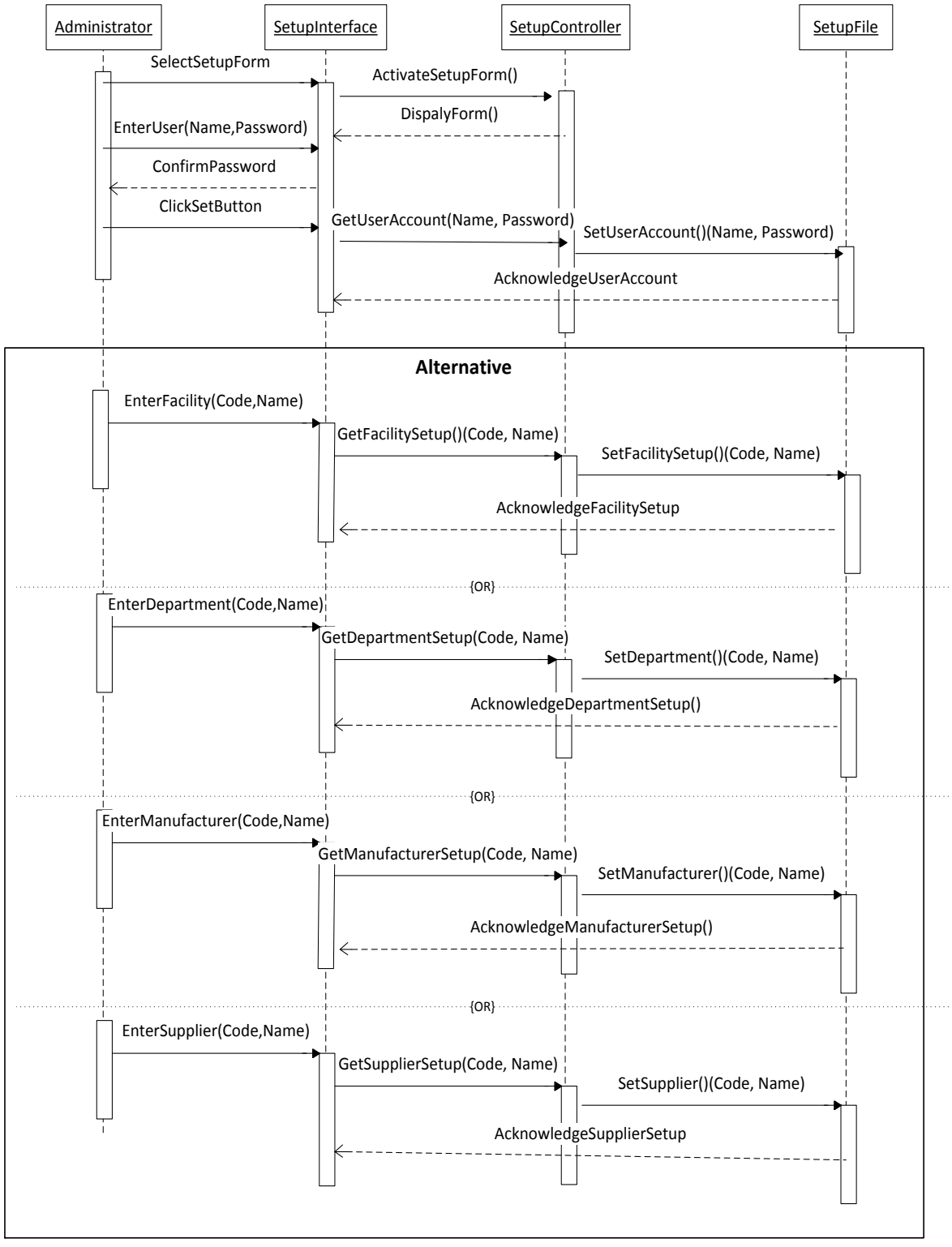


Figure 4.13: Sequence Diagram for the process of creating setup

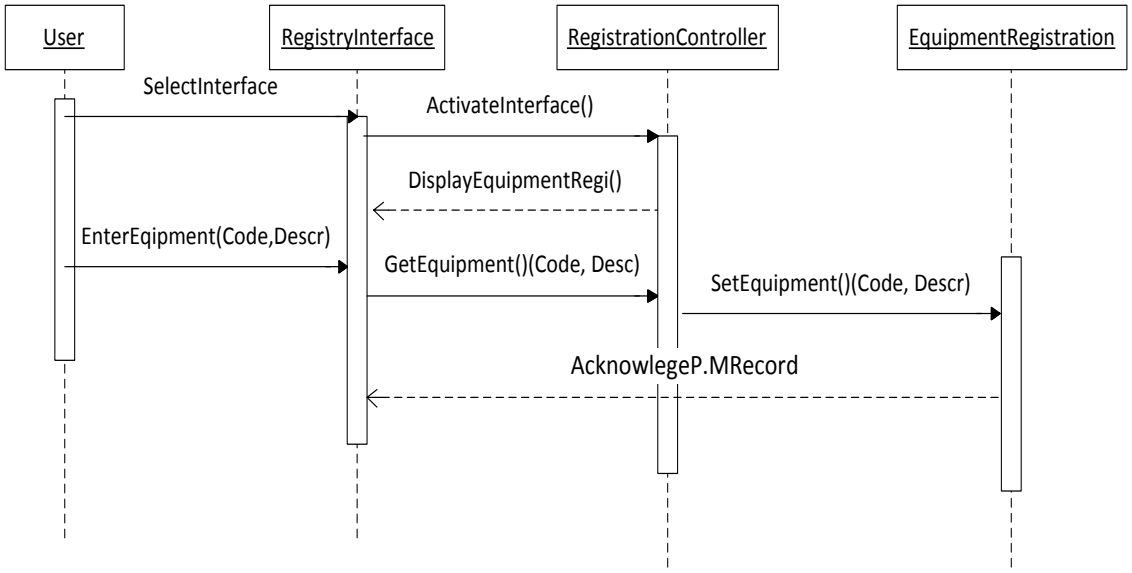


Figure 4.14: Sequence diagram for the process of registering medical equipment

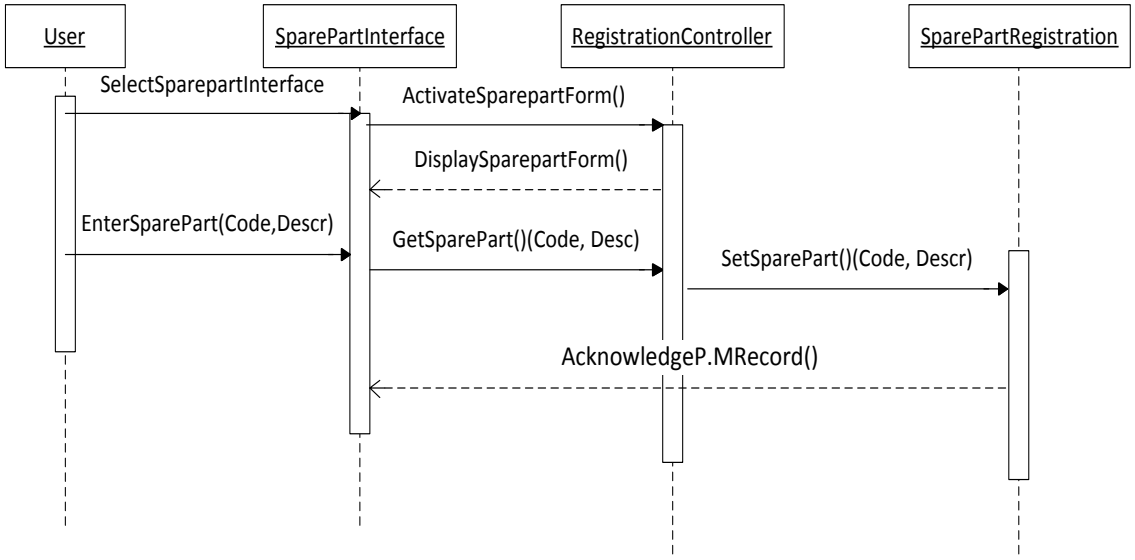


Figure 4.15: Sequence diagram for the process of registering spare part

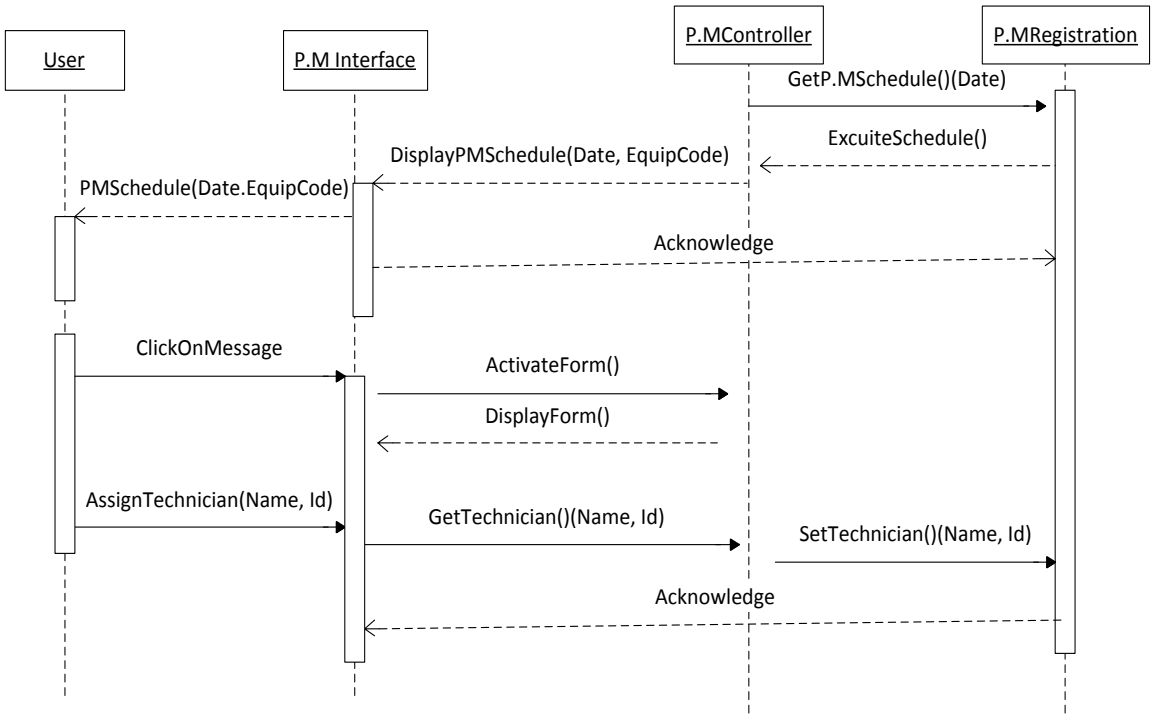


Figure 4.16: Sequence diagram for the P.M notification process

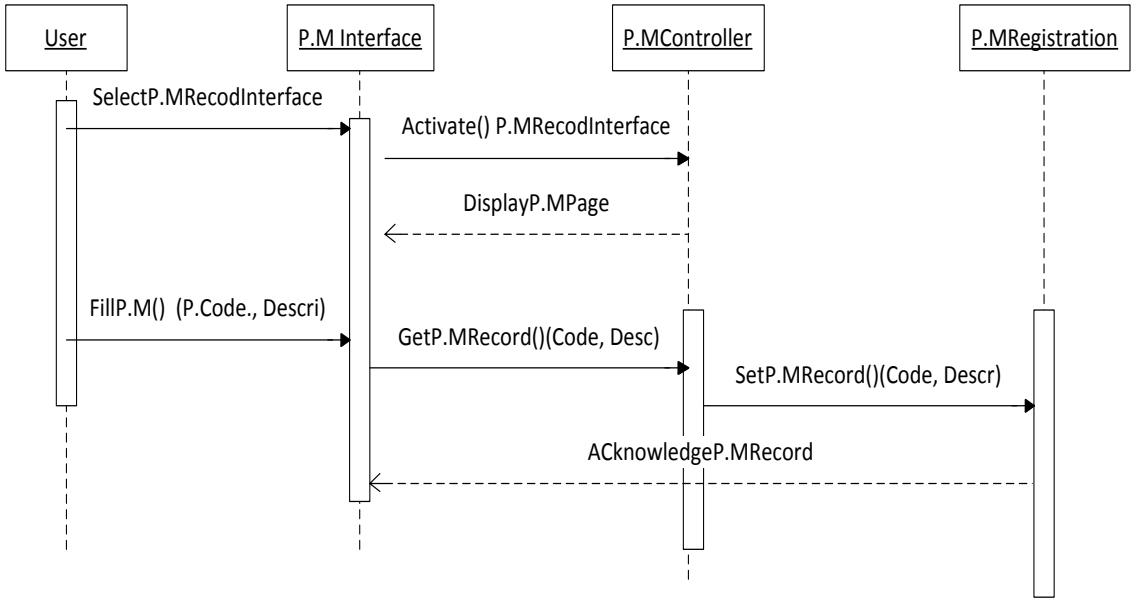


Figure4.17: Sequence diagram for the P.M recording process in the MEIMS

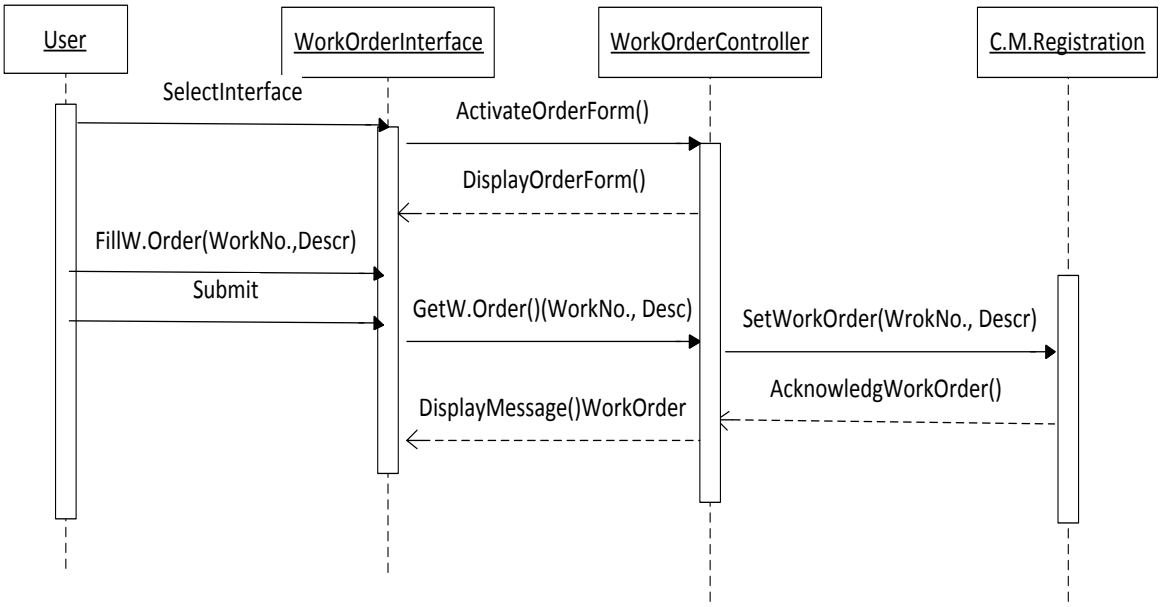


Figure4.18: Sequence diagram for the process of requesting C.M work order

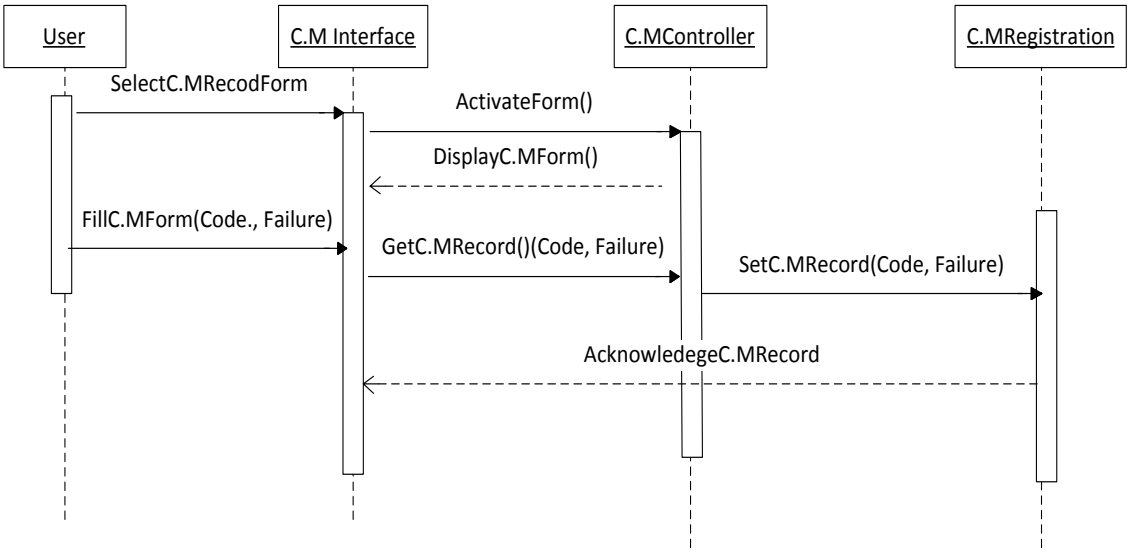


Figure 4.19: Sequence diagram for the process of recording C.M

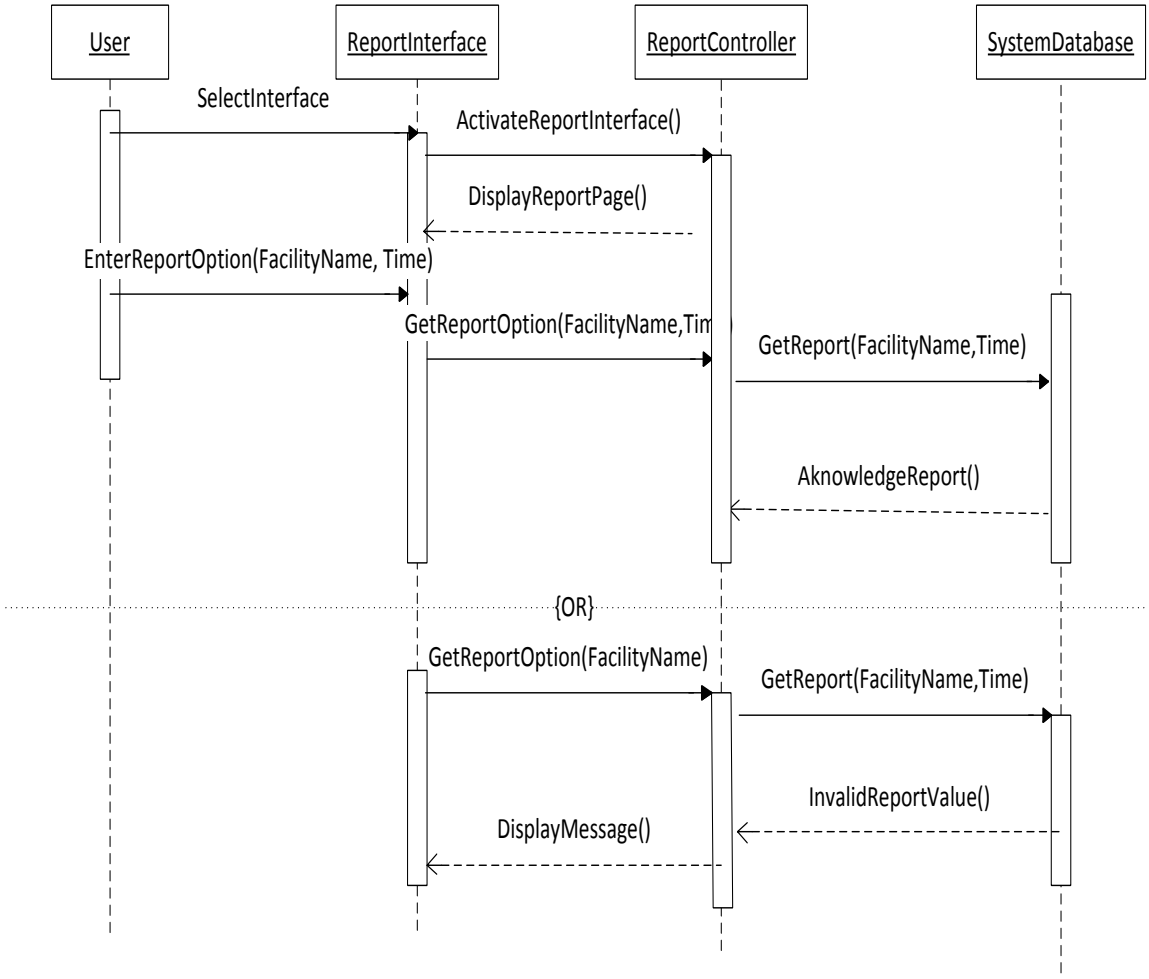


Figure 4.20: Sequence diagram for the process of report generating in the MEIMS

4.3. System Prototype Implementation

Medical Equipment Registry

Medical Equipment Registry allows the user to register new medical equipment information into the system. To open the registry form, it only needs to select medical equipment option from the main menu. It contains all information about a specific equipment need to be capture.

Figure 4.21: Medical Equipment Registry Form

Preventive Maintenance Record

Preventive maintenance uses to record preventive maintenance done for a specific equipment and the required time to complete the maintenance work. It also uses to capture spare part used for maintaining the equipment. The form is opened by selecting preventive maintenance option from the main menu.

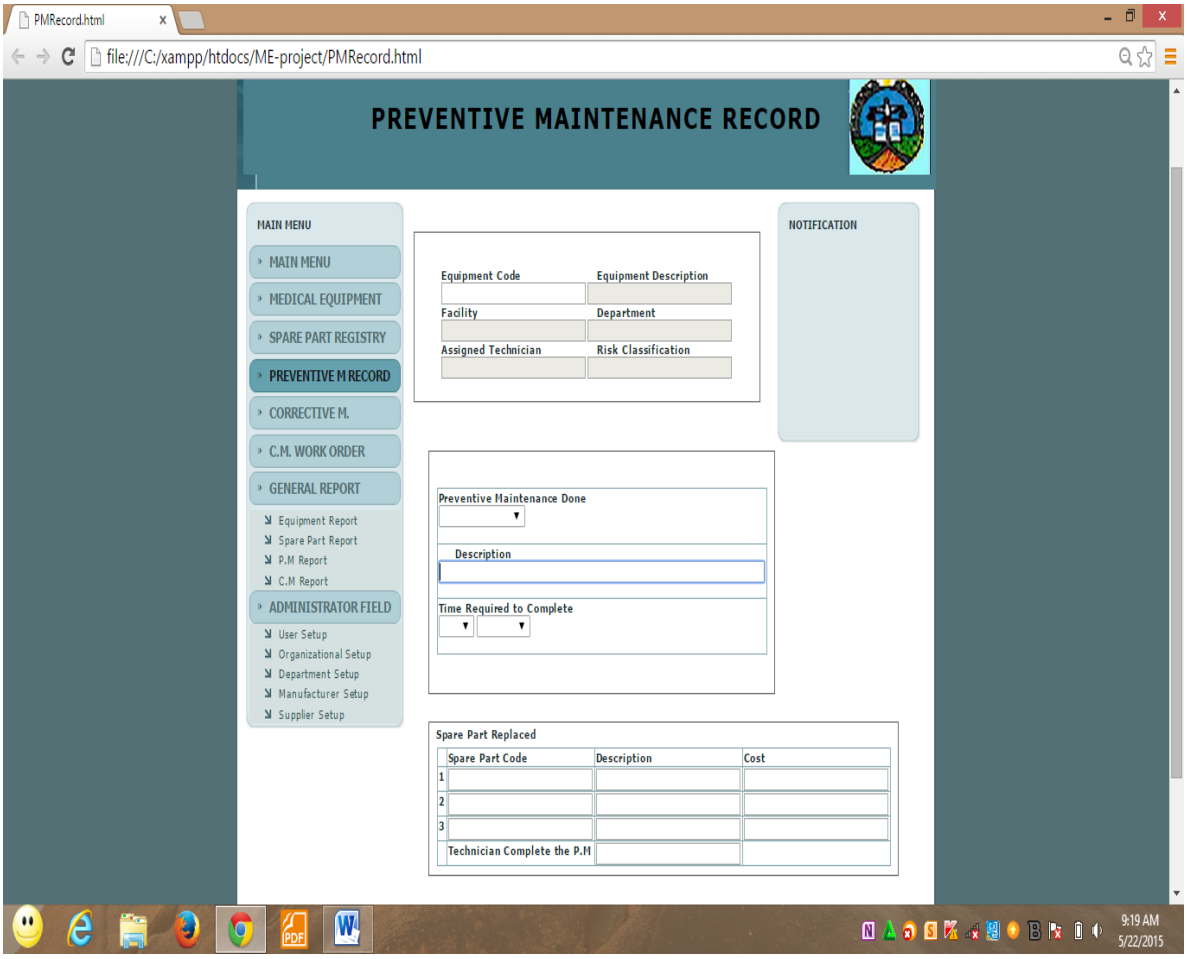


Figure 4.22: Preventive Maintenance Information Recording Form

Corrective Maintenance Report

The corrective Maintenance Report form provides an option for the user to select and generate a report about corrective maintenance done for selected duration, location and types of equipment.

Figure 4.23: Corrective Maintenance Reporting form

Corrective Maintenance Work Order

Corrective maintenance work order form helps the user to request corrective maintenance for a specific medical equipment from the central biomedical case team of the region. The user makes the request by selecting the C.M Work Order option from the main Menu and recording the initial problem of the medical equipment.

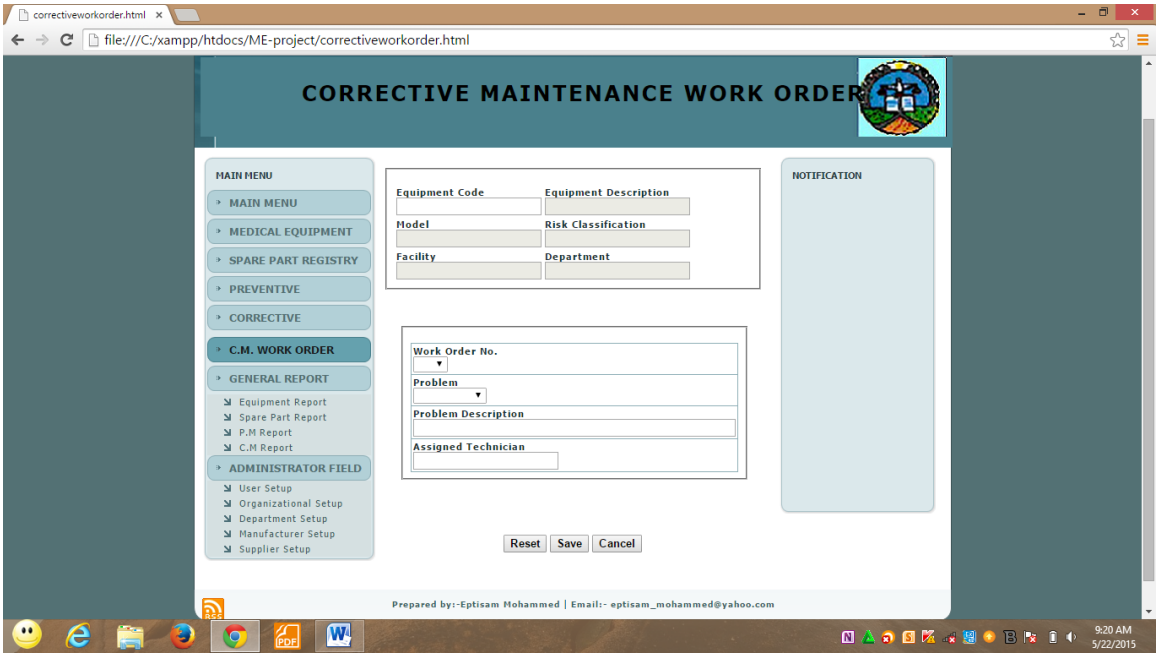


Figure 4.24: Corrective Maintenance Work Ordering Form

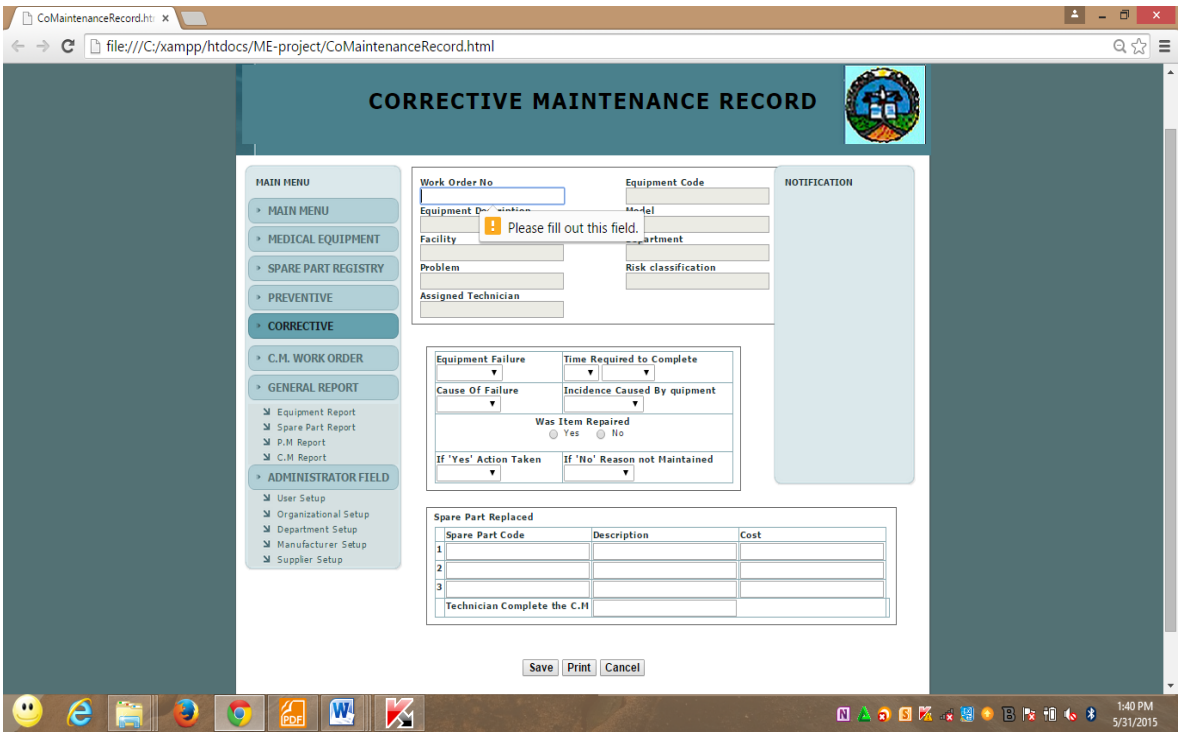


Figure 4.25: Corrective Maintenance Recording Form

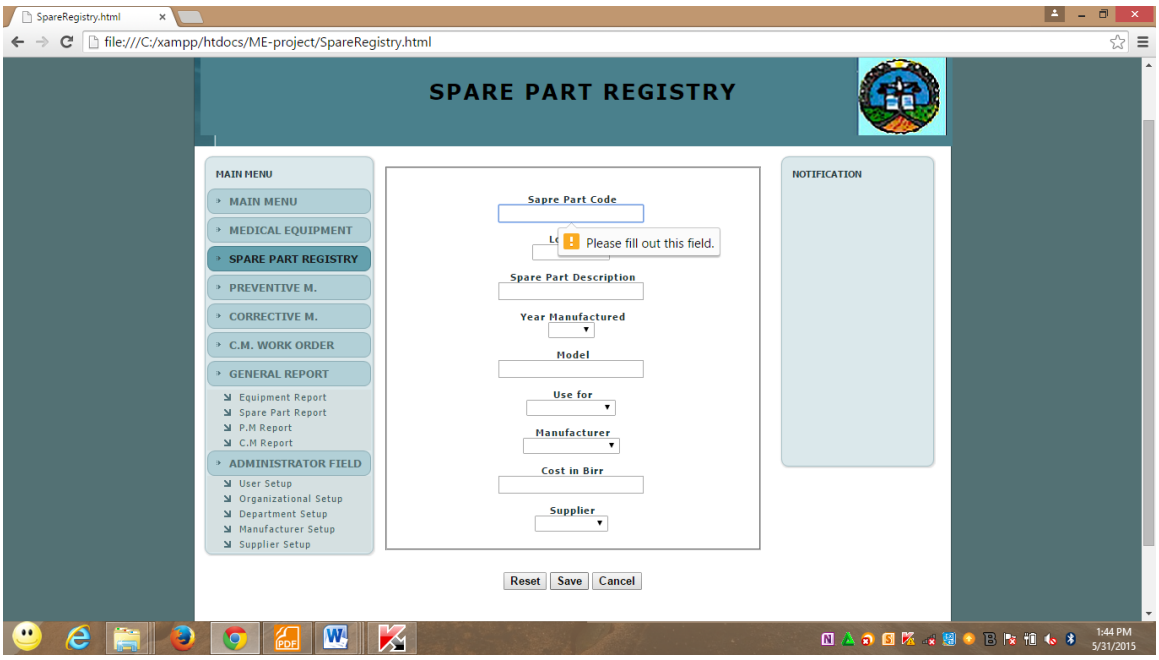


Figure 4.26: Spare Part registry Form

Figure 4.27: Medical Equipment Report Form

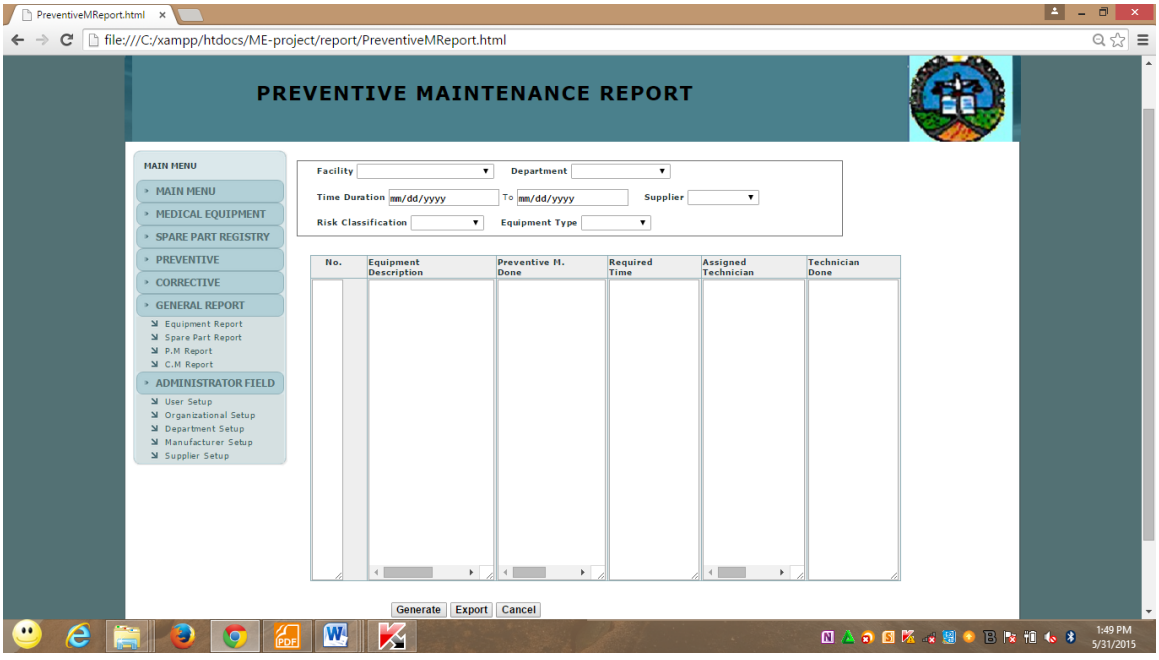


Figure 4.28: Preventive Maintenance Report Form

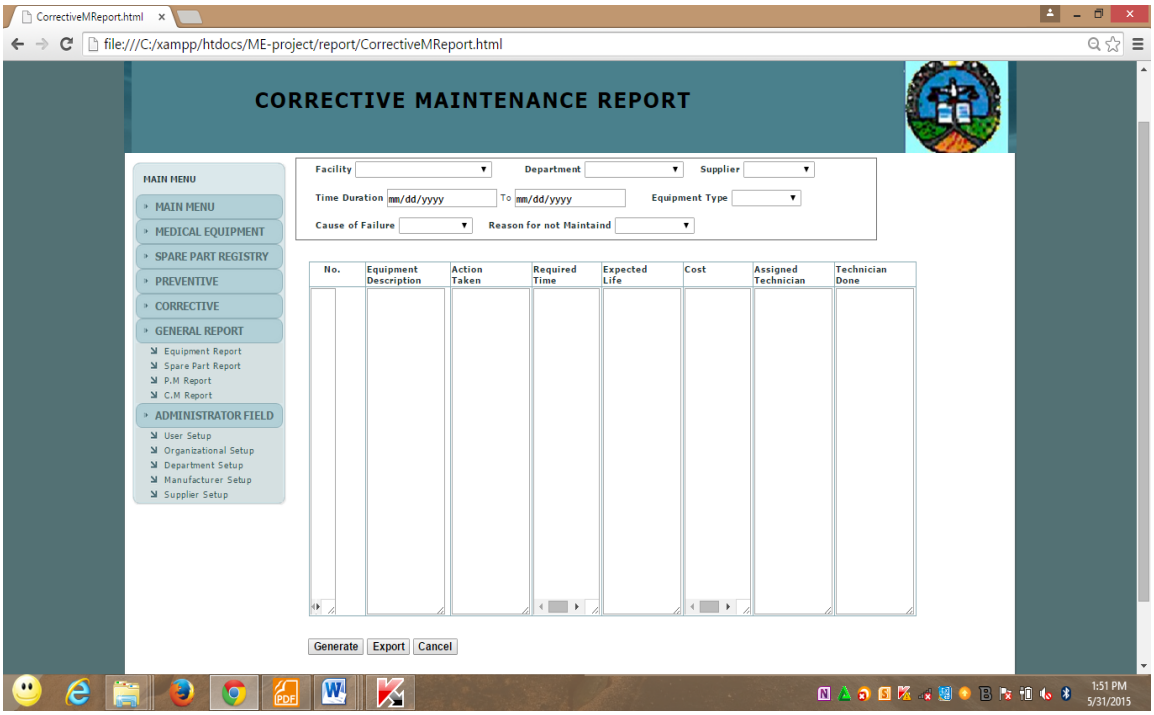


Figure 4.29: Corrective Maintenance Report Form

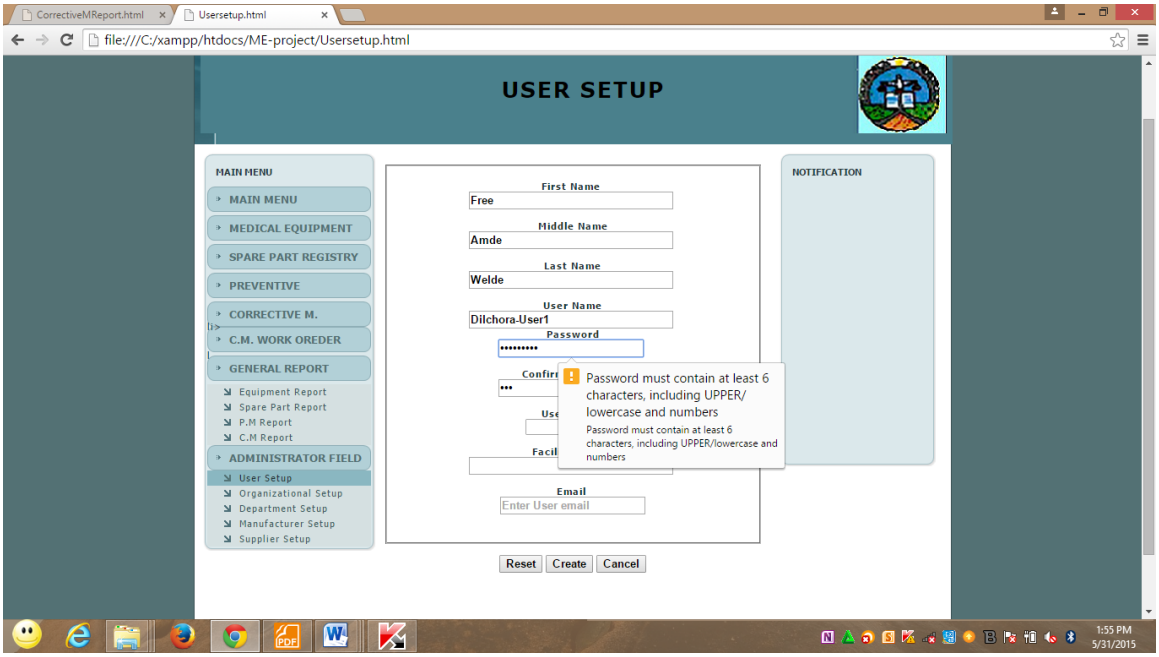


Figure 4.30: User Account Creating Form

Figure 4.31:Manufacture Setup Creating Form

Figure 4.32: Supplier Setup Creating Form

Appendix B:

Requirements Collection Check List

I. Consent Form

ADDIS ABABA UNIVERSITY

School of information science And School of public health

MSc in health informatics program

Consent form

This Interview guide is for a Design of a web-based Information Management System: The case of Dire Dawa regional health bureau.

To the respondents:

The result of this interview will be utilized for project purpose only. It is hoped that the outcome of this study will contribute to the improvement of Medical Equipment Information System Management in Dire Dawa regional health bureau. Therefore, you are kindly requested to provide genuine response to the questions that follow.

Thank you in advance for your Cooperation”

II. Data Collection Tool

In Depth Interview Guide

Data and Process

1. How does the medical equipment inventory process look like?(generally)

   _____

2. How are medical equipment problems traced out?

   _____

3. How do you control the medical equipment inventory process?

   _____

4. How do you monitor equipment status? (life cycle cost, maintenance cost, equipment replacement)

   _____

5. How do you schedule preventive maintenance for the medical equipment? , how often?

   _____

6. How do work orders come to you from facilities for corrective maintenance?

   _____

7. Do you have record of corrective maintenance done previously?

   _____

8. Can you determine equipment failure trends? How?

   _____

9. Is there any problem on the existing medical equipment management system?

_____

Report / Communication

10. How do you produce report? How often?

_____

11. For whom do you submit the report?

_____

12. How do you report?

_____

13. Does the organization have communication infrastructure in the implementation of medical equipment management system? What does it seem?

_____

People

14. How many personals (professionals) involved in the medical equipment management system? List all

_____

15. How do you identify training needs for the professionals?

_____

16. Is there any record related to professionals' performance in the case team?

Procedure (Management)

17. What is the organizational structure look like?

_____

18. Who is responsible on what?

_____

19. How do you plan for medical equipment procurement?

_____

Computer Software

20. Is there any computer software in use for the existing system? What are they?

_____

21. What are the functions of the software?

_____

22. Does the organization have plan to automate the existing medical equipment management system?

_____

23. Does the organization ready to support the development of medical equipment management information system for the biomedical case team? To what extent?

Computer Hardware

24. Is there any computer hardware being used in the existing medical equipment management information system? What are they?

_____

25. Does the organization ready to fulfill suitable hardware infrastructure in the development of medical equipment management information system? To what extent?

Document review Guide

1. Is there any recording process available for medical equipment?

   _____

2. What types of records are there?

   _____

3. What does each record include? (information included)

   _____

4. Is there any structured inventory record format?

   _____

5. What information does it include?

   _____

6. Are the records complete?

   _____

7. What is the mostly missed part in the record? Why?

   _____

8. Is there problem with the existing reporting format? What is that?

   _____

9. Who are the user of the formats ?

   _____

10. Is there a separate record for spare parts?

    _____

11. What information does it include?

Appendix C:

User interface Usability Testing Checklist

1. The interfaces are attractive

Strongly Disagree 1 2 3 4 5 Strongly Agree

2. I like the color of the interface.

Strongly Disagree 1 2 3 4 5 Strongly Agree

3. The font of the interface are Good.

Strongly Disagree 1 2 3 4 5 Strongly Agree

4. The sequence of the interface is clear.

Strongly Disagree 1 2 3 4 5 Strongly Agree

5. All important content addressed well.

Strongly Disagree 1 2 3 4 5 Strongly Agree.

6. There is too much inconsistency in the system interface.

Strongly Disagree 1 2 3 4 5 Strongly Agree.

7. I found the interfaces are very cumbersome to use.

Strongly Disagree 1 2 3 4 5 Strongly Agree.

8. The interfaces are easy to understand.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree.

9. I need more time to learn it.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree.

10. There is unnecessary content available in the interface.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree.

Declaration

I declare that this project is my original work and has not been presented for a degree in any other university, any that all sources of materials used for the project have been acknowledged.

Eptisam Mohammed

This project has been submitted for examination with our approval as university advisors.

Dr. Negussie Deyessa

Ato Ermias Abebe

Place and Date of submission: Addis Ababa, June 2015

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