Sudan University of Science and Technology

College of Graduate Studies

A Thesis Submitted in partial fulfillment for the Requirement of M.Sc Degree in Biomedical Engineering

Computerized Maintenance Management System for Medical Equipment (CMMS)

نظام محوسب لادارة صيانة المعدات الطبية

By:
Esraa Abdallah Othman Mahgoub

Supervised by:
Dr. Elias Sidieg Mohammed Hassan

SEP 2021

بسم الله الرحمن الرحيم

{وَقُلِ اعْمَلُواْ فَسَيَرَى اللّهُ عَمَلَكُمْ وَرَسُولُهُ
وَالْمُؤْمِنُونَ وَسَتُرَدُّونَ إِلَى عَالِمِ الْغَيْبِ وَالشَّهَادَةِ
فَيُنَبِّئُكُم بِمَا كُنتُمْ تَعْمَلُونَ}

صدق الله العظيم

سورة التوبة (105)

Dedication

To a strong and gentle soul who taught me to trust in Allah, believe in hard work and that so much could be done with little, my Mother. To my first teacher, guidance, promotion, who teach me to trust myself, my Father, 'Mom & Dad, you are the reason for the person I have become today'.

The words and measures can never express my deepest gratitude to my future husband Mohamed Osman Dirar. He has been a force of strength all along, and without him would have been an uphill task for me to complete this work.

Last but not least, I am deeply indebted to my sisters and my friends; their incessant support made me achieve new heights in life and built my character.

Acknowledgement

My grateful thanks to Allah for guiding me and giving me the strength to complete this project with HIS mercy, kindness and blesses. Thanks are progressed specially to D.Elias Sidieg at Sudan University of science and technology (SUST) for his wise supervisory and guidance, Eng.Omer Ashraf at Khartoum University, Eng. Sara Abdalhafez at MA Medics Company. Gratitude and thanks to Special thanks to my family who supported me all through the way, and provided me with their kindness and prayers.

Table of Contents

List of figures

ABBREVIATION

Abbreviations	Core
CED	clinical engineering department
VA	Veterans' Administration
JCAHO	Joint Commission on the Accreditation of Healthcare Organizations
QC	Quality control
QA	Quality assurance
FDA	Food and Drug Administration
WHO	World Health Organization
RBCS	Canadian Risk-Based Classification System
MTAC	Medical Technology Advisory Committee
PM	Preventive maintenance
CM	Corrective maintenance
IPM	Inception preventive maintenance

Pd M	Predictive maintenance
ISO	International organization for standardization
IEC	International electro technical commission
MEMP	Medical Equipment Management Program
CMMS	Computerized Management Maintenance system
HTM	Health Care Technology Management
ERP	Enterprise Resource Planning

Abstract

Hospitals and health care organizations possess a large number of medical devices and equipment, most of these devices and equipment are very complex and designed with modern technology, the evolution of biomedical technology has led to an extraordinary use of medical devices in health care delivery. During the last decade, clinical engineering departments (CEDs) turned toward computerization and application of specific software systems for medical equipment management in order to improve their services and monitor outcomes. Hospitals must ensure that their critical medical devices are safe, accurate, reliable and operating at the required level of performance. Equipment should be properly maintained and kept in a good running condition in order that they fulfill the objectives for which they were purchased.

In this study, A prototype system has been designed by using "ODOO" formerly known as Open source Enterprise Resource Planning (ERP), addressing all CEDs tasks for maintenance management of medical equipment. The system architecture is based on select and installs suitable modules integrated and connected together each one addressing specific predefined tasks.

The main features of this system include equipment acquisition management, inventory archiving and monitoring, follow up on scheduled maintenance, corrective maintenance, monitoring of staff performance, data analysis, and reports.

Implementation of this system improved the effective management of medical equipment with significant benefits related to cost-efficiency and safety and offered clinical engineers the ability to monitor and evaluate the quality and cost-effectiveness of the service provided by means of quality and cost indicators.

المستخلص

تمتلك المستشفيات ومنظمات الرعاية الصحية عددًا كبيرًا من الأجهزة والمعدات الطبية، ومعظم هذه الأجهزة والمعدات معقدة للغاية ومصممة بتكنولوجيا حديثة ، وقد أدى هذا التطور في التكنولوجيا الطبية الحيوية إلى استخدام متقدم للأجهزة الطبية في تقديم الرعاية الصحية. حيث خلال العقد الماضي ، تحولت أقسام الهندسة السريرية نحو حوسبة وتطبيق أنظمة برمجيات مخصصة لإدارة المعدات الطبية من أجل تحسين خدماتها ومراقبة النتائج. يجب أن تضمن المستشفيات أن أجهزتها الطبية الحرجة آمنة ودقيقة وموثوقة وتعمل على مستوى الأداء المطلوب. حيث يجب صيانة المعدات وحفظها في حالة تشغيل جيدة حتى تفي بالأهداف التي تم شراؤها من أجلها.

في هذه الدراسة ، تم تصميم نظام أولي باستخدام ODOO الذي يعرف باسم نظام تخطيط موارد المؤسسات المفتوح المصدر، والذي يتناول جميع مهام قسم الهندسة السريرية الخاصة بادارة صيانة المعدات الطبية ،تعتمد بنية النظام على اختيار و تثبيت وحدات برمجية مناسبة مرتبطة ومتكاملة مع بعضها حيث كل وحدة برمجية تتناول مهام محددة مسبقا.

هذا النظام يشتمل على إدارة اقتناء المعدات وأرشفة المخزون ومراقبته ومتابعة الصيانة المجدولة والصيانة التصحيحية ومراقبة أداء الموظفين وتحليل البيانات والتقارير.

أدى تنفيذ هذا النظام إلى تحسين الإدارة الفعالة للمعدات الطبية مع فوائد كبيرة تتعلق بفعالية التكلفة والسلامة ، كما أتاح للمهندسين الإكلينيكيين القدرة على مراقبة وتقييم جودة وفعالية التكلفة للخدمة المقدمة من خلال مؤشرات الجودة والتكلفة.

CHAPTER ONE

INTRODUCTION

1.1 General view:

A Clinical Engineer is a professional who supports and advances patient care by applying engineering and managerial skills to healthcare technology. The department of Clinical Engineering plays an important role beginning from procurement process and facilitates effective management of medical devices which are especially used in health care facilities. Additionally, clinical engineering department increases life cycle of medical devices, optimizes spare parts and technical services' costs of medical devices in order to improve the quality of health care.

Medical devices are used today in virtually every health care delivery process. Whether equipment is used for diagnosis, monitoring of patient condition, or therapy, a health care facility should ensure that its equipment is performing as intended by the manufacturer.

In order to satisfy the increased needs for medical equipment management, clinical engineering departments (CEDs) have turned to computerization as the only cost-effective solution. Software tools, specifically designed for medical equipment management, offer many benefits compared to manual paperwork, including easy storage and retrieval of enormous amounts of information and facilitation of data processes and analysis. Clinical engineering departments can manage their workloads more effectively, provide better management, and assure both efficient device operation and greater patient safety.

1.2 Problem statement:

There is no clear software system of management for clinical engineering department in health care units in Sudan to help those responsible for establishing and managing medical equipment quality control (QC) program and staff.

1.3 Hypothesis:

Enhance the healthcare by providing integrated software system for clinical engineering department management.

1.4 Objectives:

1.4.1 General objectives:

The main objective of such an integrated software system is to assist the CED in performing tasks concerning safety, effectiveness, and efficiency in use of medical equipment and staff.

1.4.2 Specific objectives:

• Find software management system simple and easy to use coordinates and connects the functions of clinical engineering department with all flexibility.

• Design integrated software management system enable the user to addition, modification and customization to fit all the need of clinical engineering department.

• Implementation and testing the software system to manage clinical engineering department in any hospital in Sudan at lowest possible cost.

• Evaluation the management system applied to the clinical engineering department to reach desired result.

1.5 Methodology:

To accomplish the desired design of software system, firstly all the related data must be collected from different sources references, papers, magazines and websites related to the clinical engineering department management and how to design that software system following the right standards from interviews, then Preparation of basics and tasks of software by set up ODOO ERP "Enterprise Resource Planning" and choose appropriate modules , then design the software system and modify source code of module to reach the desired results.

1.6 Thesis Layout:

Chapter one consists of introduction layout, problem statement and objective. Chapter two contains the theoretical fundamentals. The previous studies described in chapter three. Chapter four deal with the methodology of data collection and system design. The discussion are described in chapter five. Finally Chapter six deal with the conclusion and future work.

CHAPTER TWO

THEORTICAL FUNDMENTALS

2.1 Clinical engineer

Is an engineer who has graduated from an accredited academic program in engineering or who is licensed as a professional engineer or engineer-in-training and is engaged in the application of scientific and technological knowledge developed through engineering education and subsequent professional experience within the health care environment in support of clinical activities. Furthermore, the clinical environment is defined as that portion of the health care system in which patient care is delivered, and clinical activities include direct patient care, research, teaching, and public service activities intended to enhance patient care.

2.2 Evolution of Clinical Engineering

Engineers were first encouraged to enter the clinical scene during the late 1960s in response to concerns about patient safety as well as the rapid proliferation of clinical equipment, especially in academic medical centers. In the process, a new engineering discipline—clinical engineering—evolved to provide the technological support necessary to meet these new needs. During the 1970s, a major expansion of clinical engineering occurred, primarily due to the following events:

- The Veterans' Administration (VA), convinced that clinical engineers were vital to the overall operation of the VA hospital system, divided

the country into biomedical engineering districts, with a chief biomedical engineer overseeing all engineering activities in the hospitals in that district.

- Throughout the United States, clinical engineering departments were established in most large medical centers and hospitals and in some smaller clinical facilities with at least 300 beds.
- Clinical engineers were hired in increasing numbers to help these facilities use existing technology and incorporate new technology.

Having entered the hospital environment, routine electrical safety inspections exposed the clinical engineer to all types of patient equipment that was not being maintained properly. It soon became obvious that electrical safety failures represented only a small part of the overall problem posed by the presence of medical equipment in the clinical environment. The equipment was neither totally understood nor properly maintained. Simple visual inspections often revealed broken knobs, frayed wires, and even evidence of liquid spills. Investigating further, it was found that many devices did not perform in accordance with manufacturers' specifications and were not maintained in accordance with manufacturers' recommendations. In short, electrical safety problems were only the tip of the iceberg. The entrance of clinical engineers into the hospital environment changed these conditions for the better. By the mid- 1970s, complete performance inspections before and after use became the norm, and sensible inspection procedures were developed. In the process, clinical engineering departments became the logical support center for all medical technologies and became responsible for all the biomedical instruments and systems used in hospitals, the training of medical personnel in equipment use and safety, and the design, selection, and use of technology to deliver safe and effective health care.

With increased involvement in many facets of hospital/ clinic activities, clinical engineers now play a multifaceted role. They must interface successfully with many "clients," including clinical staff, hospital administrators, regulatory agencies, etc., to ensure that the medical equipment within the hospital is used safely and effectively. Today, hospitals that have established centralized clinical engineering departments to meet these responsibilities use clinical engineers to provide the hospital administration with an objective option of equipment function, purchase, application, overall system analysis, and preventive maintenance policies [1].

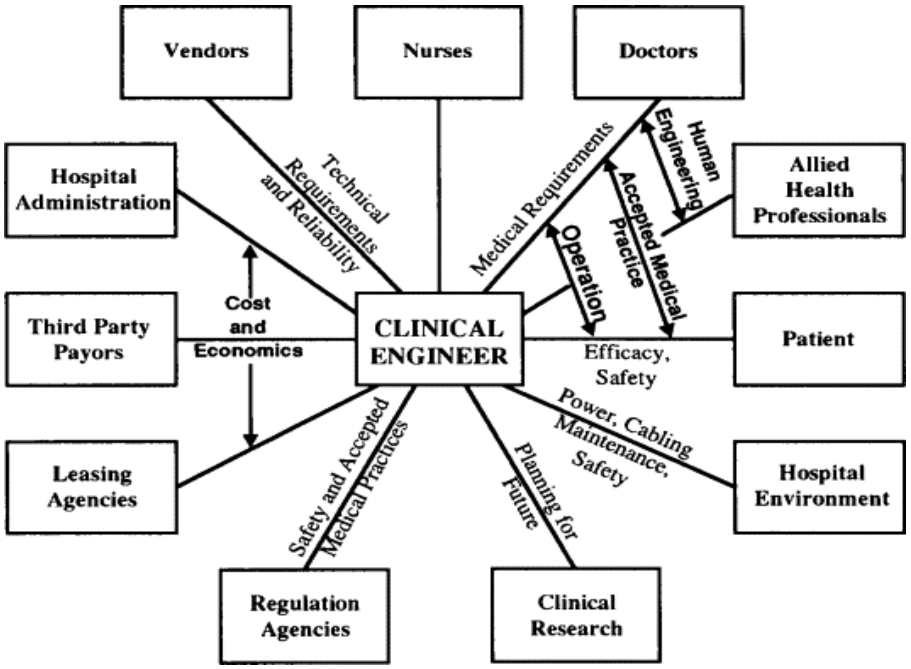

Figure (2-1): Diagram illustrating the range of interactions of a clinical engineer.

2.3 Hospital Organization and the Role of Clinical Engineering

In the hospital, management organization has evolved into a diffuse authority structure that is commonly referred to as the *triad model*. The three primary components are the governing board (trustees), hospital administration (CEO and administrative staff), and the medical staff organization

2.3.1 Governing Board (Trustees)

The Joint Commission on the Accreditation of Healthcare Organizations (JCAHO) summarizes the major duties of the governing board as "adopting by-laws in accordance with its legal accountability and its responsibility to the patient." The governing body, therefore, requires both medical and paramedical departments to monitor and evaluate the quality of patient care, which is a critical success factor in hospitals today. To meet this goal, the governing board essentially is responsible for establishing the mission statement and defining the specific goals and objectives that the institution must satisfy. Therefore, the trustees are involved in the following functions:

• Establishing the policies of the institution

• Providing equipment and facilities to conduct patient care

• Ensuring that proper professional standards are defined and maintained (i.e., providing quality assurance)

• Coordinating professional interests with administrative, financial, and community needs

• Providing adequate financing by securing sufficient income and managing the control of expenditures

• Providing a safe environment

• Selecting qualified administrators, medical staff, and other professionals to manage the hospital In practice, the trustees select a hospital chief administrator who develops a plan of action that is in concert with the overall goals of the institution.

2.3.2 Hospital Administration

The hospital administrator, the chief executive officer of the medical enterprise, has a function similar to that of the chief executive officer of any corporation. The administrator represents the governing board in carrying out the day-to-day operations to reflect the broad policy formulated by the trustees. The duties of the administrator are summarized as follows:

• Preparing a plan for accomplishing the institutional objectives, as approved by the board

• Selecting medical chiefs and department directors to set standards in their respective fields

• Submitting for board approval an annual budget reflecting both expenditures and income projections

• Maintaining all physical properties (plant and equipment) in safe operating condition

• Representing the hospital in its relationships with the community and health agencies

• Submitting to the board annual reports that describe the nature and volume of the services delivered during the past year, including appropriate financial data and any special reports that may be requested by the board

In addition to these administrative responsibilities, the chief administrator is charged with controlling cost, complying with a multitude of governmental regulations, and ensuring that the hospital conforms to

professional norms, which include guidelines for the care and safety of patients.

2.4 Clinical Engineering Programs

In many hospitals, administrators have established clinical engineering departments to manage effectively all the technological resources, especially those relating to medical equipment, that are necessary for providing patient care. The primary objective of these departments is to provide a broad-based engineering program that addresses all aspects of medical instrumentation and systems support.

Figure (2.2) illustrates the organizational chart of the medical support services division of a typical major medical facility. Note that within this organizational structure, the director of clinical engineering reports directly to the vice-president of medical support services. This administrative relationship is extremely important because it recognizes the important role clinical engineering departments play in delivering quality care. It should be noted, however, that in other common organizational structures, clinical engineering services may fall under the category of "facilities," "materials management," or even just "support services." Clinical engineers also can work directly with clinical departments, thereby bypassing much of the hospital hierarchy. In this situation, clinical departments can offer the clinical engineer both the chance for intense specialization and, at the same time, the opportunity to develop personal relationships with specific clinicians based on mutual concerns and interests. Once the hospital administration appoints a qualified individual as director of clinical engineering, the person usually functions at the department-head level in the organizational structure of the institution and is provided with sufficient authority and resources to perform the duties efficiently and in accordance with professional norms. To understand the extent of these duties, consider

the job title for "clinical engineering director" as defined by the World Health Organization.

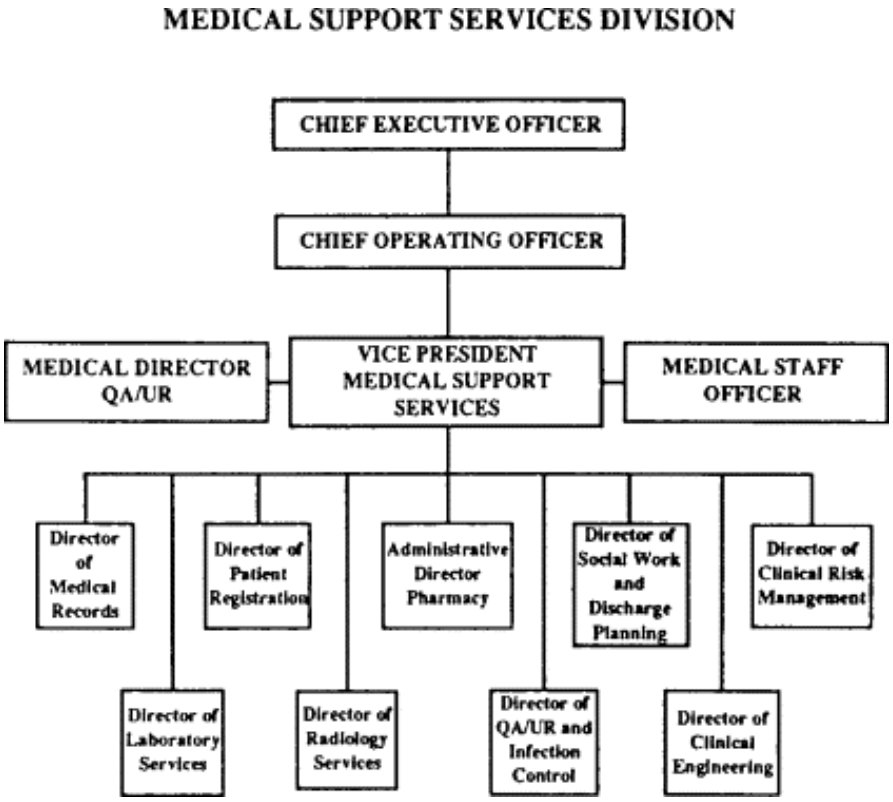

Figure (2-2): illustrates the organizational chart of the medical support services division

2.4.1 General Statement.

The clinical engineering director, by his or her education and experience, acts as a manger and technical director of the clinical engineering department. The individual designs and directs the design of equipment modifications that may correct design deficiencies or enhance the clinical performance of medical equipment. The individual also may supervise the implementation of those design modifications. The education and experience that the director possesses enables him or her to analyze complex medical or laboratory equipment for purposes of defining corrective maintenance and developing appropriate preventing

maintenance or performance assurance protocols. The clinical engineering director works with nursing and medical staff to analyze new medical equipment needs and participates in both the prepurchase planning process and the incoming testing process. The individual also participates in the equipment management process through involvement in the system development, implementation, maintenance, and modification processes.

2.4.2 Duties and Responsibilities.

The director of clinical engineering has a wide range of duties and responsibilities.

For example, this individual

• Works with medical and nursing staff in the development of technical and performance specifications for equipment requirements in the medical mission.

• Once equipment is specified and the purchase order developed, generates appropriate testing of the new equipment.

• Does complete performance analysis on complex medical or laboratory equipment and summarizes results in brief, concise, easy-to-understand terms for the purposes of recommending corrective action or for developing appropriate preventive maintenance and performance assurance protocols.

• Is responsible for obtaining the engineering specifications (systems definitions) for systems that are considered unusual or one-of-a-kind and are not commercially available.

• Supervises in-service maintenance technicians as they work on codes and standards and on preventive maintenance, performance assurance, corrective maintenance, and modification of new and existing patient care and laboratory equipment.

• Supervises parts and supply purchase activities and develops program policies and procedures for same.

• Sets departmental goals, develops budgets and policy, prepares and analyzes management reports to monitor department activity, and manages and organizes the department to implement them.

• Teaches measurement, calibration, and standardization techniques that promote optimal performance.

• In equipment-related duties, works closely with maintenance and medical personnel. Communicates orally and in writing with medical, maintenance, and administrative professionals. Develops written procedures and recommendations for administrative and technical personnel.

2.4.3 Minimum Qualifications.

A bachelor's degree (4 years) in an electrical or electronics program or the equivalent is required (preferably with a clinical or biomedical adjunct). A master's degree is desirable. A minimum of 3 years' experience as a clinical engineer and 2 years in a progressively responsible supervisory capacity is needed. Additional qualifications are as follows:

• Must have some business knowledge and management skills that enable him or her to participate in budgeting, cost accounting, personnel management, behavioral counseling, job description development, and interviewing for hiring or firing purposes. Knowledge and experience in the use of microcomputers are desirable.

• Must be able to use conventional electronic trouble-shooting instruments such as multimeters, function generators, oscillators, and oscilloscopes. Should be able to use conventional machine shop equipment such as drill presses, grinders, belt sanders, brakes, and standard hand tools.

• Must possess or be able to acquire knowledge of the techniques, theories, and characteristics of materials, drafting, and fabrication techniques in

conjunction with chemistry, anatomy, physiology, optics, mechanics, and hospital procedures.

• Clinical engineering certification or professional engineering registration is required.

2.5 Functions of a Clinical Engineer

- ***Technology Management.***

Developing, implementing, and directing equipment management programs.

Specific tasks include accepting and installing new equipment, establishing preventive maintenance and repair programs, and managing the inventory of medical instrumentation. Issues such as cost effective use and quality assurance are integral parts of any technology management program. The director advises the administrator of the budgetary, personnel, space, and test equipment requirements necessary to support this equipment management program.

- **Risk Management.**

Evaluating and taking appropriate action on incidents attributed to equipment malfunctions or misuse. For example, the clinical engineering director is responsible for summarizing the technological significance of each incident and documenting the findings of the investigation. He or she then submits a report to the appropriate hospital authority and, according to the Safe Medical Devices

- **Technology Assessment.**

Evaluating and selecting new equipment. The director must be proactive in the evaluation of new requests for capital equipment expenditures, providing hospital administrators and clinical staff with an in depth appraisal of the benefits/ advantages of candidate equipment. Furthermore,

the process of technology assessment for all equipment used in the hospital should be an ongoing activity.

- **Facilities Design and Project Management.**

Assisting in the design of new or renovated clinical facilities that house specific medical technologies. This includes operating rooms, imaging facilities, and radiology treatment centers.

- **Training.**

Establish and deliver instructional modules for clinical engineering staff as well as clinical staff on the operation of medical equipment. In the future, it is anticipated that clinical engineering departments will provide assistance in the application and management of many other technologies that support patient care, including computer support, telecommunications, and facilities operations.

2.6 Medical equipment:

Medical equipment means any means any instrument, apparatus, implement, machine, appliance, implant, reagent for in vitro use, software, material or other similar or related article, intended by the manufacturer to be used, alone or in combination, for human beings, for one or more of the specific medical purpose(s) of:

- Diagnosis, prevention, monitoring, treatment or alleviation of disease.
- Diagnosis, monitoring, treatment, alleviation of or compensation for an injury.
- Investigation, replacement, modification, or support of the anatomy or of a physiological process.
- Supporting or sustaining life.

- Control of conception.
- Disinfection of medical devices.
- Providing information by means of in vitro examination of specimens derived from the human body.

And requiring calibration, maintenance, repair, user training, and decommissioning − activities usually managed by clinical engineers [2].

Basic medical equipment is commonly used in the healthcare organizations. It is helpful to present primary healthcare to the public. World Health Organization (WHO) classifies essential medical equipment in four main categories based on the use of the equipment for a specified health service delivery (World Health Organization, 1998).

Each individual hospital authorities decide which type and what number of these devices are required for their own health service purposes.

The main categories of World Health Organization (WHO) are:

- General electro-medical equipment
- Laboratory equipment
- Diagnostic imaging equipment
- Other support equipment [3].

2.6.1 Medical Equipment Classifications:

The Food and Drug Administration (FDA) has established classifications for approximately 1,700 different generic types of devices and grouped them into 16 medical specialties referred to as panels. Each of these generic types of devices is assigned to one of three regulatory classes based on the level of control necessary to assure the safety and effectiveness of the device. The three classes and the requirements which apply to them are:

1. Class I General Controls

- With Exemptions
- Without Exemptions

2. Class II General Controls and Special Controls

- With Exemptions
- Without Exemptions

3. Class III General Controls and Premarket Approval

In addition, classification is risk based, that is, the risk the device poses to the patient and/or the user is a major factor in the class it is assigned. Class I includes devices with the lowest risk and Class III includes those with the greatest risk. [4]

European Union classification of medical devices:

All medical devices are placed into one of four graduated categories, using the classification rules. It is considered more feasible, economically and justifiably, to categorize medical devices rather than all of them being subject to the rigorous conformity assessment procedures. The categories are**:**

- Class I
- Class IIa
- Class IIb
- Class III, with Class III ranked as the highest.

Considerations for classification include the duration of contact with the body, degree of invasiveness and local versus systemic effect. The highest possible class applies if a device can be classified according to several rules. [5]

Canadian classification of medical devices:

Similar to the European Union, Health Canada applies a four-tier classification system to medical devices according to their risk to the

human body, with Class I representing the lowest risk to the human body and Class IV representing the highest risk.

Medical device classifications are determined by the Canadian Risk-Based Classification System (RBCS), under the auspices of the Therapeutic Products Division (TPD) of Health Canada. If a medical device can be classified in more than one class, the higher class applies. [6]

2.7 Medical Equipment Management:

Medical Equipment Management (MEM) takes place within the context of human, material, structural, organizational, and financial resources. It is a process which helps hospitals to develop, monitor, and manage their equipment to promote the safe, effective, and economical use and maintenance of equipment. Responsible organizations should setup and regularly review MEM to ensure that a suitable medical device is used in accordance with the manufacturer's instructions, maintained in a safe and reliable condition, and disposed appropriately at the end of its useful life.

A systematic way to manage medical equipment is to study and optimize all phases in the useful life of that equipment. A typical life cycle approach that was originally developed for major medical equipment also applies to non-major but essential medical devices and may be extended to additional devices. It is a logical sequence of medical equipment management activities or stages, and each stage is dependent on and linked with other activities. It consists of nine stages as follows:

2.7.1 Planning

Planning process is an important aid in decision-making because it provides essential information for management. In other words, it provides technology vision where healthcare facility should position itself; it can

specify the following conditions in order to aid the decision-making process.

• Demonstrated needs and benefits

• Available qualified users

• Confirmed maintenance services and support

• Adequate environment support

• Regulatory compliance

These conditions are simple and should be applied to any routine acquisition of a medical device. A policy on medical device acquisition meeting these conditions as prerequisites to acquisition will reduce problems later in the life cycle of the device. For example, appropriate financial planning for a medical device can ensure optimum position for operating and service costs of this device.

Planning is the responsibility of the Medical Technology Advisory Committee (MTAC). The committee includes an administrator, a planning director, and a clinical engineering director. The role of planning is to ensure a balance between clinical and technology sectors of healthcare facilities in addition to meeting the community needs. The procedure of strategic planning of medical equipment includes:

• Performing an initial audit for existing technologies

• Conducting a technology assessment for new and emerging technologies that fit the desired clinical services

• Planning for replacement and selection of new technologies

• Setting priorities for acquisition

• Developing processes to implement equipment acquisition, and monitor ongoing utilization

2.7.2 Acquisition

Healthcare industry is known for its continued innovation and production of new devices and techniques intended to improve the delivery and outcome of patient care. Funding constraint is considered the master key to evaluate incorporation of new technology to healthcare service. Thus, more attention should be given to the acquisition process keeping in mind both healthcare delivery outcomes and funding availability. Acquisition stage usually incorporates four main processes as shown in Figure (2.3).

Needs identification usually starts from users of technology, i.e. the medical staff (physicians and nurses).Indeed, the need to acquire a medical device may be due to one or a combination of the following reasons:

• Provide a new service

• Improve service efficiency

• Improve clinical outcomes

• Improve cost benefits

• Meet specific standards

• Reduce a risk.

In general, tendering process takes place to purchase medical equipment based on the required specifications. In tendering, all vendors are allowed

to bid under a competitive and fair evaluation. Moreover, it gives a good opportunity for hospitals to select the best possible medical equipment. It is worthy to mention that technical specifications should include general requirements such as the warranty, technical services, technical documents, and any other necessary requirements for equipment operation.

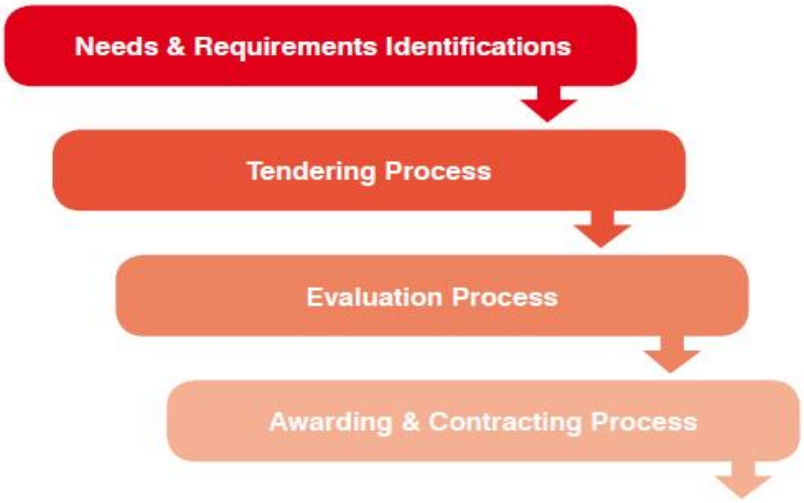

Figure (2-3): processes of acquisition stage

In the evaluation process, the purchased medical equipment should be evaluated from three different angles: technical, clinical, and financial. The purpose of technical and financial evaluations is to check the proposed technology, and to ensure the performance of the devices meets the desired outcomes. On the other hand, financial evaluation considers only the costs of the proposed technology. Both technical and clinical evaluations are carried out using either scoring or accept/reject approaches, whereas financial evaluation regards the lowest price among accepted vendors.

After making the selection, an award must be issued to acquire the device. A purchase contract document is prepared by the purchasing department and it must cover all terms and conditions that have been agreed upon by the vendor and the hospital.

2.7.3 Delivery and incoming inspection

Clinical engineering department ensures an incoming inspection on equipment includes verification of accessories, manuals, and electrical safety and operation in accordance with all applicable policies. Incoming equipment should be carefully checked for possible shipment damage and compliance with specifications in the purchase order. One role of clinical engineer is to ensure an incoming inspection on medical equipment by verifying the following:

• Accessories existence

• Manuals existence

• Electrical safety

• Compliance with specifications

• Possible shipment damage

2.7.4 Inventory and documentation

Medical device inventory and documentation is an assistive stage in the life cycle. It provides information to support medical equipment management in different stages. Upon completion of the incoming inspection, a device record file should be created and it should be active throughout the useful life span of the device. Each device is identified and tracked by a unique number called equipment record number. The device record file should contain the following data:

• An Equipment Control Number (ECN)

• A generic description of the equipment

• The equipment manufacturer, model, and serial number

• The owner department and the location of the equipment

• The purchase order number and date

• The equipment's acquisition cost

• The supplier's name, address, and telephone number

• The warranty conditions and expiration date

• An abbreviated description of the inspection and preventive maintenance requirements and intervals

• An abbreviated service history

• Information regarding any applicable service contract

• The location of the equipment's user and service manuals.

2.7.5 Installation and commissioning

Installation and commissioning can be carried out by in-house technical staff if they are familiar with a given item of equipment. If the installation and commissioning are needed from the suppliers, in-house technical staff should monitor this process. In general, installation process should be compatible with standard policies for medical equipment installation.

2.7.6 User Training

To reduce the possibility of equipment malfunction following service or repair, all personnel involved in maintaining and servicing equipment must be trained to appropriate standards for the work they are carrying out. Operator error is a leading cause of device malfunctioning, especially in

developing countries. Incorrect usage of medical equipment will also greatly increase maintenance problems. Therefore, training of users should be regularly monitored from the vendor to ensure an appropriate skill level that is required for equipment operation. In fact, training should include all of the user staff as needed, such as clinical and technical staff. In addition, it should cover all aspects of medical equipment usage.

2.7.7 Monitoring of use

One common mistake in MEM is to believe that the warranty period is covered by the supplier, so no in-house technical attention is necessary. In-house technical staff should become the link between user and supplier and should observe any supplier's technical staff. This also will provide a learning opportunity for the in-house technical personnel. This performance should be also documented in the service history of the device by in-house technical staff.

2.7.8 Maintenance

Equipment maintenance involves all activities related to providing an adequate level of service and limiting downtime of medical devices. Maintenance or service activity is required in order to ensure the devices are kept functioning within the limits imposed by the test criteria and to return devices to the required level of functioning after breakage or other failure. The primary goal of maintenance activity is to reduce, or, if possible, to eliminate the need of repairs

2.7.9 Replacement

Replacement is the last stage of medical equipment's life cycle. All medical devices reach the point in their life where the cost-benefit ratio goes to the negative because of decreased reliability, increased downtime,

safety issues, compromised care, increased operating costs, changing regulations, or simply obsolescence. A synopsis diagram that illustrates the replacement process in terms of participants, inputs, and output is shown in Figure (2.4).

Disposal of equipment must follow safety procedures in order to protect people and the environment. The ideal healthcare technology replacement planning system should be facility wide, and cover all clinical equipment employ accurate objective data for analysis. Moreover, it should be futuristic and include strategic planning relating to clinical marketplace trends and the hospital's strategic initiatives relating to technology. The plan should encompass factors relating to cost-benefit analysis, safety, expected life span, standardization, and clinical benefits. In application, decontamination requirements should be regarded prior to disposal. Furthermore, many benefits can be obtained by utilizing scrapped equipment as listed below:

• Use spare parts with similar equipment

• Replace with new ones with the same vendors

• Donate them to charity clinics after operation verification

• Dummies in internal training

• Use in research labs

• Save them for museums.

In fact, most of hospital planning processes tend to focus on current or short-term needs with little or no consideration of future replacement of medical equipment. An equipment replacement plan will help to guide the

hospital on potential future spending obligations relating to medical devices. Different approaches are used for replacement of medical equipment. These approaches are either qualitative or quantitative. In qualitative approach, a combination of different criteria is regarded to approve replacement decision; whereas in quantitative approach, a mathematical model is proposed to determine replacement thresholds which lead to a realistic replacement decision. [7]

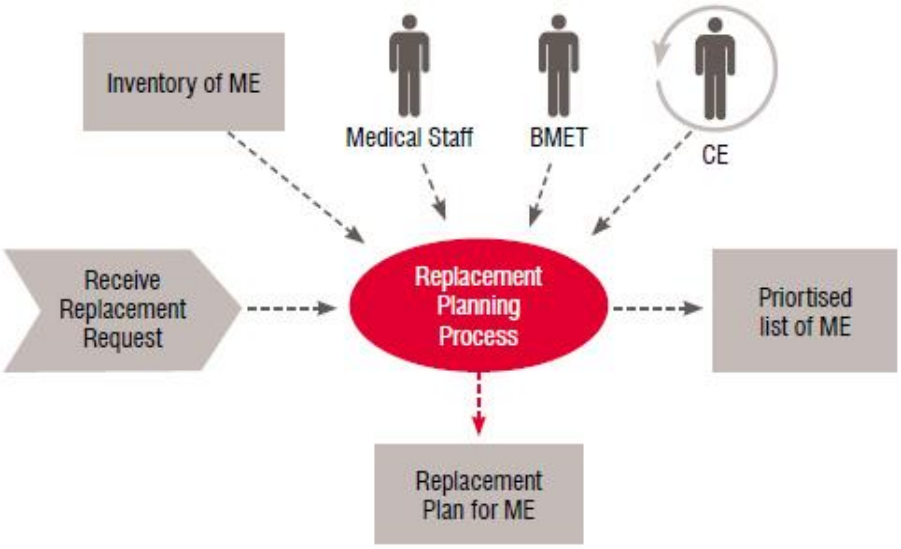

Figure (2-4): replacement process

2.8 Maintenance of Medical Equipment:

Medical equipment maintenance can be divided into two major categories: inspection and preventive maintenance (IPM), and corrective maintenance (CM). IPM includes all scheduled activities that ensure equipment functionality and prevent breakdowns or failures. Performance and safety inspections are straightforward procedures that verify proper functionality and safe Use of a device. Preventive maintenance (PM) refers to scheduled activities Performed to extend the life of a device and prevent failure (i.e. by calibration, part replacement, lubrication, cleaning, etc).

Inspection can be conducted as a stand-alone activity and in conjunction with PM to ensure functionality; this is important as PM can be fairly invasive in that components are removed, cleaned or replaced. It is essential for any health-care facility, regardless of its size, to implement a maintenance programme for medical equipment. The complexity of the programme depends on the size and type of facility, its location, and the resources required. However, the principles of a good maintenance programme will be the same if it is in an urban area in a high-income country or a rural setting in a low- to middle-income country.

2.9 Preventive Maintenance of Medical Equipment:

Preventive maintenance is predetermined work performed to a schedule with the aim of preventing the sudden failure of equipment's components.

- **Real benefits of Preventive Maintenance (PM) system:**
  - Increases operator, maintenance mechanic, and public safety.
  - Reduces downtime (increase uptime).
  - Increases equipment availability (available whenever needed).
  - Lowers cost/unit (output-cost per ton of coal, cost per widget, and cost per student).
  - Allows corrective maintenance to be scheduled when equipment is not needed.
  - Reduces damage to associated components.
  - Reduces the size and scale of repairs.
  - After a plant tour PM increases the chance a customer will give your business.
  - Reduces number of repairs.
  - Increases equipment's useful life.
  - Reduces investment by not needing spare or stand-by units.

- Increase quality of output.
- Reduces overtime for responding to emergency breakdown.
- Increases accountability for all cash spent.
- Increase potential exposure to liability.
- Increase control over parts, reduces inventory level.
- Insure that all parts are used for authorized purposes.
- Reduces the chance for regulatory fines and sanctions.
- Improve identification of problem areas to show where to focus S attention.
- Improves information available for equipment specification.
- Lowers overall maintenance cost through better use of labor and materials. [8]

- **The two main parts of a PM:**

1. Procedure: The procedure is the parent key to the schedule that is created using the PM easy form.

2. Schedule: The schedule is created second and lists the specific detailed to accomplish the procedure. It defines who, what, where and when of a procedure. [9]

Preventive maintenance (PM) schedule, service contracts, safety procedures, measurement points, multiple meters, inspection routes, specification data (name plate), equipment downtime, and related documentation. This equipment data is used for managing day-to-day operations and historical data that can be used to help make cost effective replace or repair decisions. The data can also be used to develop additional management information, such as building equipment downtime failure code hierarchies for use in maintenance management metrics. [10]

- **Predictive maintenance (Pd M):**

By common agreement, the phrase predictive maintenance means Maintenance that that includes some instrument or technology. Properly, any instrument can be used for predictive maintenance if it is indeed used predicatively (predictive maintenance is about how you use the data). For example, predictive inspections can come from existing equipment used in new ways, including volt/ohm meters, mergers, and measuring instruments. All the predictive techniques should be listed on a task list and controlled by the PM system.

Medical devices usually undergo several types of tests/inspections during their life cycles as described here:

- **Acceptance Test:**

A series of qualitative and quantitative tasks designed to verify the safety and performance of newly received equipment, as well as conformity to applicable codes, regulations and standards.

- **Operational Check**:

Visual and operational check of the equipment's safety and functionality typically performed at the beginning of the day or work period, or just before using equipment on a patient.

- **Safety and Performance Inspection (SPI) :**

A set of qualitative and quantitative tasks designed to verify the safety and performance of each piece of equipment by detecting potential and hidden failures and taking appropriate actions.

After accomplishing the acceptance test for a newly received device, SPIs are scheduled to be performed periodically. If any problem is found at inspection, corrective actions are taken to restore the device or its defective parts to an acceptable level. In addition, a set of failure preventive actions may be taken to prevent future failures and/or restore device function; these

include part replacement, calibration, lubrication, etc. to address age or usage related deterioration.

The PM/Inspection procedures should be based on need that includes the maintenance requirements of the device, risk classification, device function, and history of incidents. Maintenance and performance inspections do not prevent random failures, particularly related to electronic equipment and low risk devices do not need performance verification at the same frequency or intensity of higher risk devices.

2.10 Computerized Maintenance Management Systems:

A CMMS is a software package that contains a computer database of information about an organization's maintenance operations.

In health-care technology management, the CMMS is used to automate the documentation of all activities relating to medical devices, including equipment planning, inventory management, corrective and preventive maintenance procedures, spare parts control, service contracts, and medical device recalls and alerts. The collected data can be analyzed and used for technology management, quality assurance, work order control and budgeting of medical devices [11].

In order to effectively assist in the management and maintenance of medical equipment, a CMMS must comprehensively meet the needs of the user.

The following information should be tracked by the medical equipment management software

- **Basic device information:** Any medical equipment management software should track basic device information. At a minimum, the

device type, manufacturer, model, and serial number should be tracked. This information is essential to the maintenance program.

- **Clinical use:** The clinical use of a device should be documented. Equipment used for life support needs to be given a higher priority for maintenance. Additionally, regulations on life support devices may be different.
- **Location:** This may be entered as the owner department or a physical location. The equipment location is used to find the equipment for maintenance. Also, the location is useful to break up the maintenance schedules by department.
- **Maintenance history:** A record should be kept of all maintenance performed on equipment, including scheduled maintenance, repairs, software upgrades, and incident investigations. Dates of service should be included in this history.
- **Work coding:** A work order is generated for each maintenance event and a work order type is assigned to each work order. Work order coding is important in measuring the success of the maintenance program and for identifying areas that need to be addressed. [12]

A CMMS package integrates all medical equipment services into a database made up of fields, tables, modules and screens.

A CMMS can be used to:

• standardize and harmonize information within a health-care technology management program

• assist in the planning and monitoring of inspection and preventive maintenance and schedule and track repairs

• monitor equipment performance indicators such as mean time between failures, down time and maintenance costs for individual or equipment groups of the same model, type or manufacturer

• monitor clinical engineering staff performance indicators such as repeated repairs by the same staff member for the same problem, average down time associated with individuals, and productive work time for individuals or groups

• generate reports that can be used to plan user training programs based on equipment failure trends in certain departments or health facilities

• host libraries of regulatory requirements and safety information;

• generate the appropriate documentation for accreditation by regulatory and standard organizations

• generate reports to assist in the monitoring and improvement of the productivity, effectiveness and performance of health-care technology management.[13]

2.10.1 CMMS Core Modules:

A module is a collection of tables and data screens. The inventory module, for example, is made up of the ‘equipment type’ table, the ‘manufacturer information’ table and the ‘equipment location’ table.
The following sections describe the basic modules of a CMMS package.

- **Equipment inventory module:**

The inventory module is the core of any CMMS and the first to be constructed. When new equipment is added to the inventory, the equipment is registered within the CMMS database through a data entry screen.

It is common practice to use stored default values to build inventory records for new equipment, as it reduces entry time and avoids human error.

Similarly, the other areas illustrate default values associated with the equipment model, location of medical equipment and inventory number, respectively. This allows modules to be built with maximum efficiency and maintains data integrity.

- **Spare parts inventory and management module**

The spare parts management module is an extension of the inventory module that tracks the spare parts related to equipment and helps to maintain stock levels.

Stocked parts include those that are common to a number of different pieces of equipment such as fuses, wires, batteries and basic electronic components, and those parts that are more specific to a particular model such as circuit boards, power supplies, X-ray tubes and ultrasound probes. Some CMMS packages provide a fully automated operation that includes all phases of spare parts management from procurement to delivery, acceptance testing and use. Fields in the spare parts inventory might include:

• Part description (name);
• stock (inventory) number;
• Manufacturer’s name, serial and part number;
• Link to equipment model;
• Minimum stock level;
• Current stock level;
• Part storage location;
• Price and date purchased.

- **Maintenance module**:

The maintenance module assists the user of the CMMS program to effectively manage their maintenance schedule.

The CMMS can be used for both planned preventive maintenance and corrective maintenance.

- **Planned preventive maintenance:**

With the appropriate inputs, the computerized system can calculate when a piece of equipment will require maintenance and advise which parts might need to be ordered and when. The package can also monitor the maintenance process and log when it has been completed.

- **Corrective maintenance:**

When an equipment user reports a problem with a piece of equipment, the clinical engineering department can log the fault in the CMMS system.

The program will automatically generate a work order and allow the manager of the system to assign an engineer to the job.

The CMMS program can provide information regarding workload, training and expertise of individual engineers to assist with this decision. If an initial evaluation of the fault identifies that a specific part is required to complete the job, the computerized system can record this and provide the appropriate ordering information about the part. When the job is complete the status of the equipment can be logged in the system.

- **Contract management module**

The contract management module is used to track all externally provided maintenance services. The main factors to monitor are cost and performance of both vendor and equipment. If the medical equipment is under contract, either through warranty, comprehensive service contracts or partial support service contracts, the vendor is required to provide technical support to the equipment over an agreed period.

- **Screens and reports**

A screen allows the user to add, collect and analyse data from a selection of fields, tables and modules through a user-friendly interface. For example, the ‘equipment history’ screen is a collection of data from various modules summarizing the HTM activity related to a certain piece of equipment. It is the main feature of a CMMS and includes information such as the inventory details, service activities, work order details, spare parts used and associated costs, and recall information. Screens can be used to generate reports that will assist in monitoring the activities related to the management of medical equipment. This helps managers to evaluate the overall performance of their HTM system.[14]

2.11 Enterprise Resource Planning (ERP) Defined

The term ERP stands for Enterprise Resource Planning. It refers to the systems and software packages that organizations use to manage daily business operations, transactions and activities related to Sales, Purchases, Accounting and Finance, Manufacturing, Project management and other business modules. ERP systems tie together and define a pool of business processes and enable the flow of data between them. ERP systems collect shared transactional data of an organization from different possible sources and store, manage and analyze, interpret this data related to multiple business activities. They help to eliminate data redundancy and duplication and provide data integrity with a “single source of truth.” ERP refers to business-management software which is a suite of integrated applications related to core business processes all under one roof. It provides complete

visibility to all the vital and significant processes across various functional departments of an organization. It manages these business processes in real-time and mediated by software and technology. An ERP systems objective is to integrate back office processes related to different business modules and enable necessary flow of information within an organization required to make data-driven business decisions. ERP systems assist in improved internal and external business communication. These systems can be customized and extended to provide Business intelligence functionalities that can provide high-level insights on existing on-going business processes and hence can help to solve problems and identify potential areas of improvements.

2.12 "ODOO" - An Open Source ERP

"ODOO" (formerly known as OpenERP) is one such open-source ERP software framework most widely used by different companies across the globe. "ODOO" provides numerous modules and business applications under one-roof such as Sales, Purchases, Warehouse, Accounting, Human Resources, Helpdesk, Manufacturing, Project Management, Website/ECommerce etc. – helping to record the business data and transactions, tracking their status, enabling integration and inter-relationships between different business modules, developing and optimizing business workflows, developing dashboards and deriving Reports to track the progress of business

operations from Management perspective. The organizations belonging to different industry domains world-wide such as Information Technology, Manufacturing, Retail, Education, Health care, Publishing, Travel, Transportation and Logistics opt for the development and customization of "ODOO" ERP applications as per their needs and client requirements.

"ODOO" is a multitenant three-tier architecture. The application tier itself is written as a core, multiple additional modules can be installed to create a particular configuration of "ODOO".
The core of "ODOO" and its modules are written in Python (programming language).

Some of the core benefits of open source ERP system are listed below:

- **Less Expensive**

Open source ERP system minimize business cost of organization in a long run. i.e., open source ERP system does not require any license to run the system. There is no maintenance cost associated with open source ERP's as most of them offer community based support.

- **Flexibility**

Open source ERP systems provide more flexibility than proprietary ERP systems. In many cases, while implementing open source ERP system in a large company, a new interface is

created to meet the business needs of the organization making it less complex in nature. This flexibility gives open source ERP system to easily upgrade to newer version without much hassles compared to commercial ERP systems.

- **Absolute Ownership**

Another benefit of open source ERP system is that the organizations have full control over the system they invested and the source code. Everything (both technical and domain information) related to open source ERP system is available online and further knowledge can be gained from open source communities. This creates less dependency on the vendor and gives the client more freedom on how to go about the implementation. i.e., having technical and domain expertise, organization itself can implement the system or hire a vendor.

- **Quality Assurance**

The existence of open source ERP systems are based on the contributions and enhancements provided by the passionate cum independent developers who bound to give endless support to open source technologies. So a competition will arise among these developers which make them active in the community, criticizing the code developed and providing valuable contribute to the community.

- **Easily Upgradable**

Open source ERP systems are easier to upgrade customization is mostly done at the interface level without changing the framework of the system. Since the framework is not modified, the upgrades can be done easily without interrupting the production server

CHAPTER THREE

PREVIOUS STUDIES

Francisco J. Acevedo et al in (2005) the purpose of this project was to design and implement a Computerized Maintenance Management System (CMMS) to be used at the Chilean Naval Hospital Biomedical Engineering Department. The entire daily Biomedical Engineering Department work activity and processes were studied before the software was developed following the generic Clinical Engineering Maintenance Management System. In addition, best practices from three Connecticut hospital CMMS's were obtained, matching the types of reports generated and modifying them to meet the specific needs of a military hospital. Microsoft Visual Basic was used to display the visual interfaces, and Microsoft Access as a supporting database. This powerful tool will assist managers in their decision support process by converting vast amounts of available data into information, which is ultimately transformed into knowledge to enable better decision making according to the specific needs of the Hospital [15].

N. Medhat et al, in (2008) ,this paper represents a medical equipment quality assurance system by building a systematic approach through software package for quality control and assurance of medical equipment performance within the health care quality system. The goal is to have a highly effective and accurate device that provides patient with required treatment. The biomedical engineer has the full support from technical manager and division director to provide and arrange high quality calibration and testing for medical devices at the hospital. The study covers all stages that the medical equipment passes through it during its lifetime. The study includes building, monitoring and evaluating the system to

modify it when needed. Future works are gathering all input parameters in one equation to make evaluation for the medical equipment, choosing threshold values for the output parameters and applying the system on more medical equipments [16].

W.S. Trarawneh et al, in (2008),This paper describes the tools and programs used by the Quality Assurance and Quality Control (QA&QC) department to monitor, control and evaluate activities carried out by the Directorate of Biomedical Engineering (DBE) at Jordanian Ministry of health (MOH) (30 hospital, 712 medical centers). The implemented QA&QC programs and procedures include measurement and monitoring of several performance indicators for services provided by DBE. The local designed Computerized Clinical Engineering Management System (CCEMS) is used to implement QA&QC procedures to monitor , analysis and evaluate different CE activates within DBE . The results of the implemented QA&QC tools and programs prove significant improvement of DBE activities for last three years test and exam all related DBE works and activities. The QACD reviews in cooperation with DBE top management the QMS every 6 months to ensure its continuing suitability, adequacy and effectiveness. The QACD conducts internal audits at planned intervals to determine whether the QMS conforms to the planned arrangements, related requirements of international standards, QMS requirements established by DBE and if it is effectively implemented and maintained. The QACD applies suitable methods to monitor, measure and control of customer satisfactions, different QMS processes and provided services. For this purpose different tools are used such as: planned and unplanned inspections and tests, data available within the CCEMS, measuring and test equipment and the costumer complains [17].

Chia-Hung Chien et al in (2010), designed a framework of medical equipment management system used for in-house clinical engineering department. The system was web-based, and it integrated clinical engineering and hospital information system components. The system network architecture was designed under the consideration of data safety and work performance. This was divided into three parts. First, the intranet in hospital connects the overall operating computers of hospital and the hospital information system (HIS). HIS sends some basic information of medical equipment (such as budget, purchase, and property information) to the MEMS. The inner users can also access MEMS through the intranet. Second, the MEMS was set up in the intranet of CED and connected to the intranet of the hospital through a router. This system has run in the National Taiwan University Hospital. The results showed only few examples in the error analysis of medical equipment by the maintenance sub-system. The information can be used to improve work quality, to reduce the maintenance cost, and to promote the safety of medical device used in patients and clinical staffs [18].

Calin Corciova et al, in (2011), this paper represents a multi-criteria decision-making model to prioritize medical devices according to their criticality. Devices with higher criticality scores can be assigned a higher priority in a maintenance management program. A computerized medical management system is described. The results demonstrate that it is a useful tool in tracking device inventory and maintenance history. Also risk classes have been designed for medical devices based on the time of testing, risk must be identified in relation to patient and personal staff. The results of this paper take into consideration the advances in device reliability, reduced preventive maintenance requirements, and internal device surveillance (self-test) along with changes in standards. The importance of

maintenance activities is to effectively manage the equipment; this task necessitates complex information about the medical device. Thus it is necessary to make an archive of what happened in the past, to tell if the situation improves and you learn from previous situations.

Finally, record maintenance activities provide the staff valuable technical information and evidence that they can use when they need argues need help or additional resources. Data base system maintenance helps keep health service records of repairs and other actions [19].

Waleed M. M. AL-Talabi, in (2012) discussed the Quality Management System for Medical Devices. Formed a set of questions and assumptions about the problems related to quality management of medical devices covering different phases of their life cycle, and the survey published electronically for targeted audience by e-mail. Also it was posted on some Internet pages like discussion groups, social network sites, and forums. Results were collected and analyzed, in order to quantify the size of the quality management system problems with a goal in mind to design a system dynamic tool that may help the decision maker to strike a balance between quality and cost for medical device projects. The most frequent problems cited in the survey are: poor training, poor supplier's qualification, and a lack of qualified clinical engineers. Also the average life of a typical medical device in Arab countries was about 65.8% of its expected life, with a total cost exceeding the expected life cost by 29.34%. Concluded that it seems that the procedures of medical device management are going in one direction from input to output via the processes without feedback in most cases. So it is time to move from the classical medical device management style to the deeper concept of quality management systems for medical devices [20].

David Mutia et all, in (2012), this research paper evaluated the existing facilities maintenance management practices and processes in major hospitals in Kenya. The facility managers from major hospitals were interviewed on medical equipment management. The data collected from the facility managers determined their effectiveness as they managed the life cycle of the medical equipment. The results offered management the opportunity to appraise the overall maintenance program and sought improvement for increased efficiency and more effective utilization of available resources. The challenges encountered in this research included hospital's policy and technological resources. The facility maintenance management in the public hospitals was not effective as they were ranked forty percent on their performance. The maintenance computer program was developed to improve the existing facilities maintenance management for hospitals in Kenya. The program guides the user on the causes of the fault, possible personnel to handle the fault and establishment of inventory system of medical equipment [21].

CHAPTER FOUR

METHODOLOGY AND SYSTEM DESIGN

4.1 Methodology

Research methodology was built up with observations, study, problem definition, data gathering, an experimental design, and finally conclusion. According to the targeted domain, observations have been done by visiting the clinical engineering department in hospitals with expectation of identifying real scenario. Here, an interview had been conducted with the staff members of clinical engineering department. The activities of the department has been described as step by step. The collection data has been evaluated and analyzed and then the needed information was extracted.

Computerized maintenance management system that solved the research problem has been designed by using "ODOO" formerly known as Open source Enterprise Resource Planning (ERP).

4.2 Implementing CMMS

Clinical engineering staff must be included in the entire CMMS planning and implementation process. Figure (4.1) summarizes a basic seven-step process for implementing a CMMS.

- **Evaluation**

It is important to conduct a feasibility study to evaluate and assess the need for a CMMS. During this phase, a complete analysis is conducted and the scope of the system is defined. Decisions are made regarding the function of the system, and the data required to meet this function are identified.

- **Selection**

An HTM programme may range from fully paperless to fully automated using a CMMS. Therefore, the amount of features in a CMMS can vary and selection of those features will be based on the needs of the user, who may wish to fully or perhaps only partially automate the management system. Once specifications for a system have been identified, an appropriate package can be selected. It may be one that is commercially available, customized to the health facility's needs or designed specifically for the user.

- **Data collection**

A comprehensive survey and analysis of all available data should be conducted before implementing the CMMS. This information may already be available at the health facility, but some may need to be collected from other sources.

- **Installation**

Before installing the system, a system administrator is assigned who is responsible for the technical maintenance of the system and for managing data security.

- **Configuration and customization**

Configuration and customization with existing mechanisms and procedures are performed before data entry. Configuration of the system could cover areas such as simple workflow, access and security, and user preferences. Customization refers to the technical functional requirements of the system including custom screens and tables, facility-specific workflow and additional data fields

- **Data entry**

This phase consists of initial data entry of common fields such as equipment model number, inventory code, human resources, equipment locations, manufacturer information.

- **Training**

It is important that each staff member of the clinical engineering department is fully confident and familiar with all functions of the CMMS. It is useful to begin staff training in the early stages of implementation to increase staff buy-in and improve confidence.

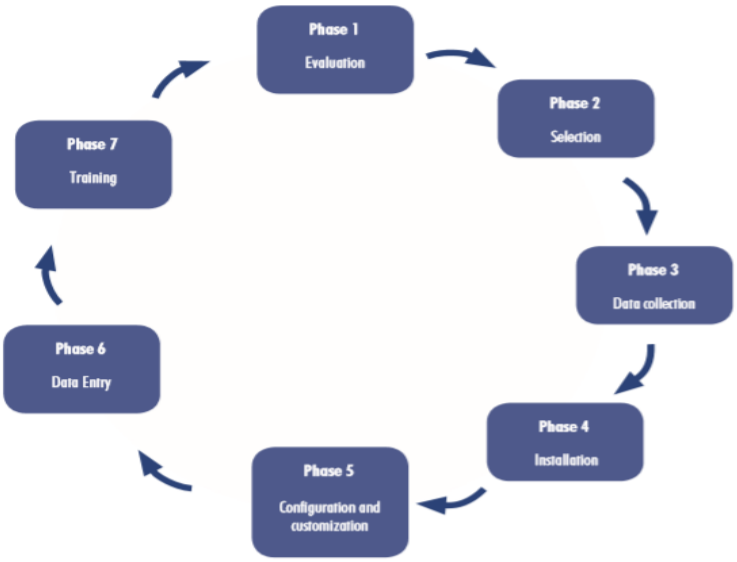

Figure (4-1): basic seven-step process for implementing a CMMS.

4.3 System Design

The steps of designing the parts of the CMMC using the ODOO ERP have been described below in addition to explaining the program contents and how to use it to have the desired results.

4.3.1 Basic Configurations of Odoo

The ODO system is a web application that is used by any modern browser, as it relies on modern web technologies. All major system components contained in a single installation package can be downloaded and installed easily from https://www.odoo.com/page/download on own computer, a local server or a web server. After installing the system, a website will be created. The very next step is setting up the database. It is in this Database all data and operations are performed. Can create multiple databases if needed, and you can have different administrators for each of them. An administrator account (super user) will be created automatically when creating the first DB. This Administrator account is very important

as he enjoys complete control over the ERP system. Odoo provides extra level security called Master password to protect the database from unauthorized modifying. May have multiple databases and administrators but only the administrator with Master Password can modify the entire database. Once configured a database, Odoo provides the option to delete, Backup, Restore the databases. Backup and Restore option is a useful feature provided by Odoo to protect the database. After setting up the database, it is time to install the modules needed from Odoo Apps and this window appeared as in Figure (0-2).

When installing Odoo in the system automatically redirected to the database creation page. On that page, Odoo provides basic instructions for creating a database that shown in Figure (4-3)

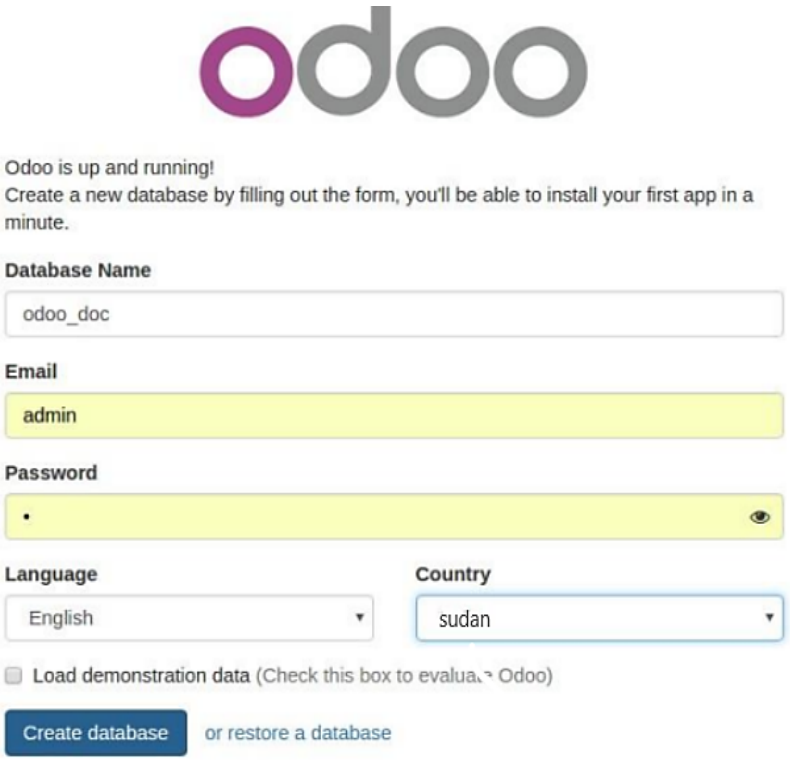

Figure (4-2): database creation page

Click <Create Database> and will be redirected to Odoo Apps. Can see the Apps from the app list, install any module according to need. In this system was installed 5 modules: inventory module, vendors module, maintenance module, employee module, discuss module

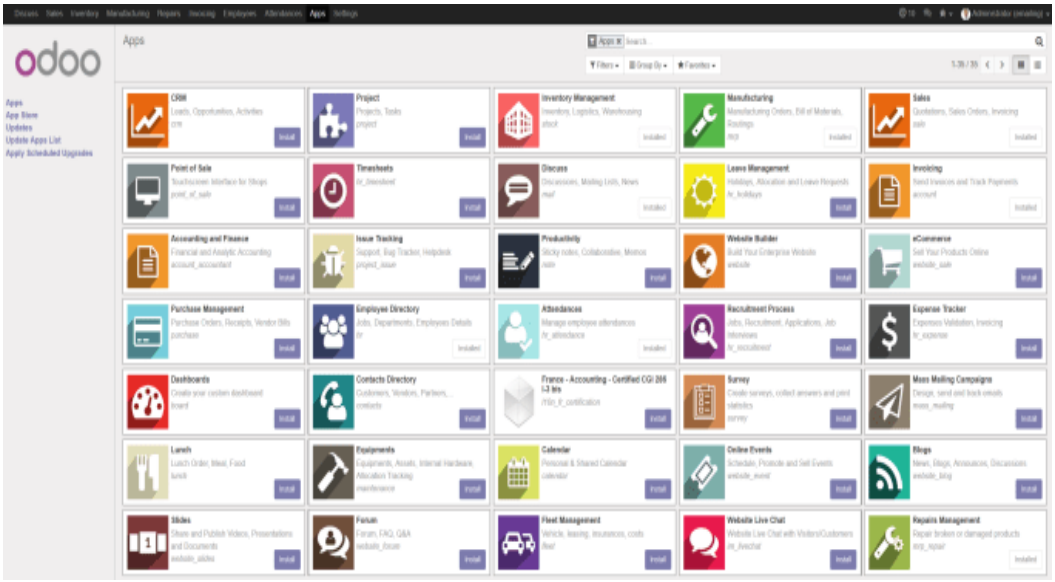

Figure (04-3): *Apps list*

4.3.2 USER Management

Basically, there are two types of users in Odoo ERP, Administrator, and normal user. Administrator is the default user created at first and he has complete access over Odoo system. As the administrator of the database, responsible for its usage. This includes the Apps install as well as the number of users currently in use etc. Admin can create as many as users and assign their permissions and access rights within the application. By this method, admin can create organizational hierarchy and restrict users only to their own domain.

- **Creating user**
  - Login to the system as administrator
  - Settings -> Users -> Create as shown in Figure (4-4) .

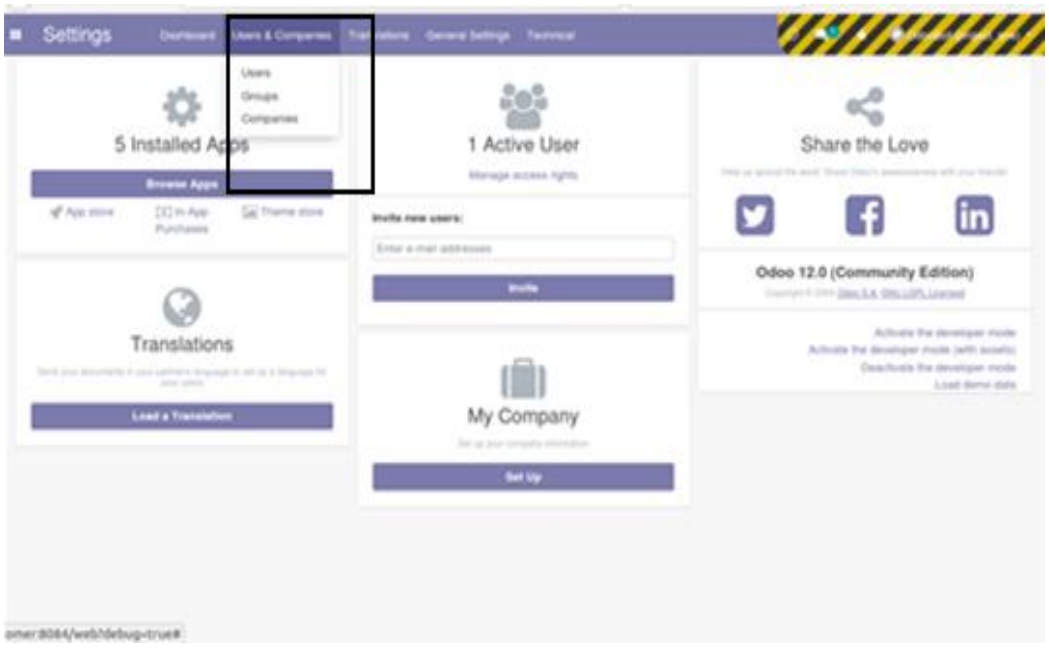

Figure (4-4): Settings page

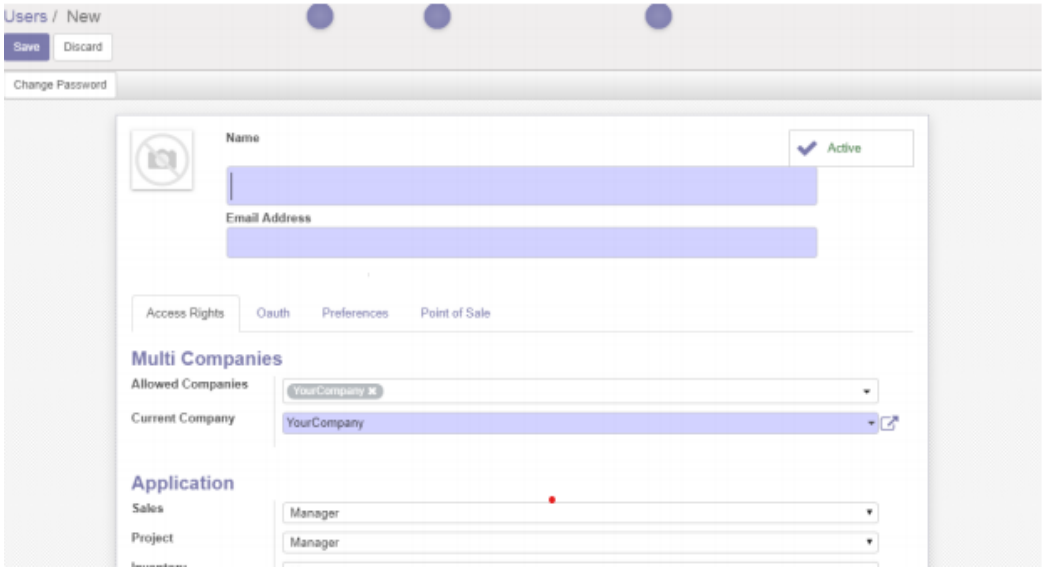

Figure (4-5): page of Creation user

- Fill the field with user information
- Set Access Rights to each application for the user from the dropdown
- Find more customization for the user in ‘Oauth’, ‘Preferences’, ‘Point Of sale’ tabs.

- ‘Change Password’ button can be used to set a password for the user

Note: - can restrict a user from accessing a particular application by changing Access Right for That application show in Figure (4-4)

Note: - Admin can edit any user details from the same menu (i.e. More->Settings->Users) by Clicking on the user name from the list show in figure (4-5)

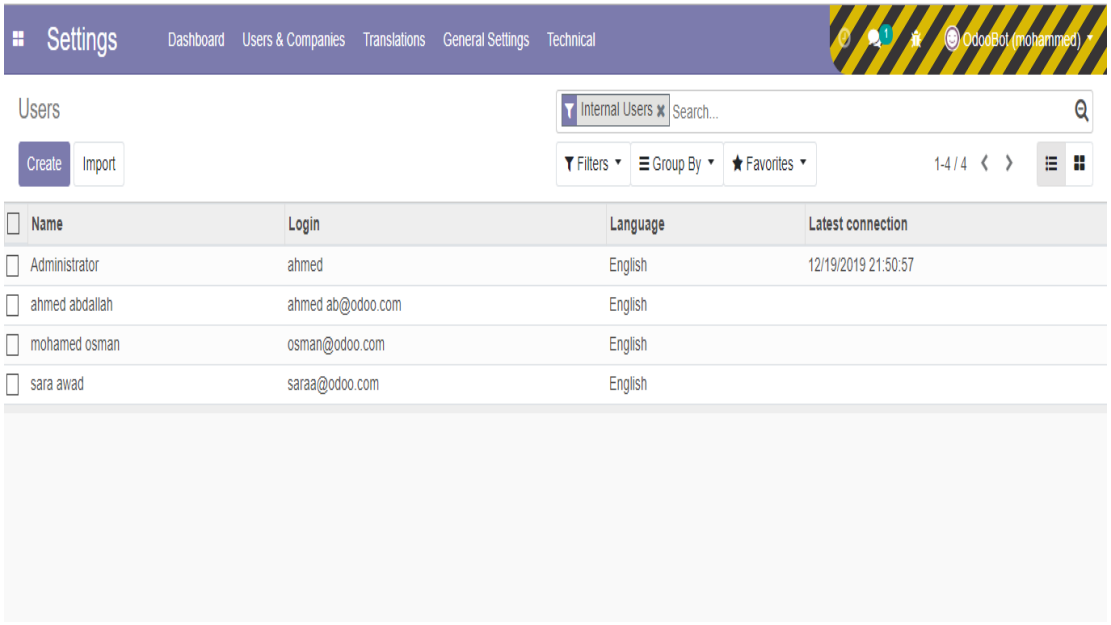

Figure (4-6): Users list page

4.3.3 ODOO Modules

- **Inventory module**
  - **Equipment inventory**

An inventory is a detailed itemized list of equipment held by a CED. To be worthwhile, an inventory must be continually maintained and updated to reflect the current status of each equipment. The goal is to have an accurate, up-to-date record of all equipment held by the hospital,

• A medical equipment inventory provides a technical assessment of the technology on hand, giving details of the type and quantity of equipment and the current operating status.

• The inventory module provides the basis for effective facilitating scheduling of preventive maintenance and tracking of maintenance, repairs, alerts

• The inventory module can provide financial information to support economic and budget assessments.

• Items equipment history files and logbooks, operating and service manuals, testing and quality assurance procedures and indicators are created, managed and maintained under the umbrella of the equipment inventory module.

. Furthermore, spare parts inventories are directly correlated with the main medical equipment inventory

- **Create new equipment**

Can add new equipment by clicking create in the main screen of equipment inventory screen and this screen shows the list of all other equipment as appears as a figure (4-7).

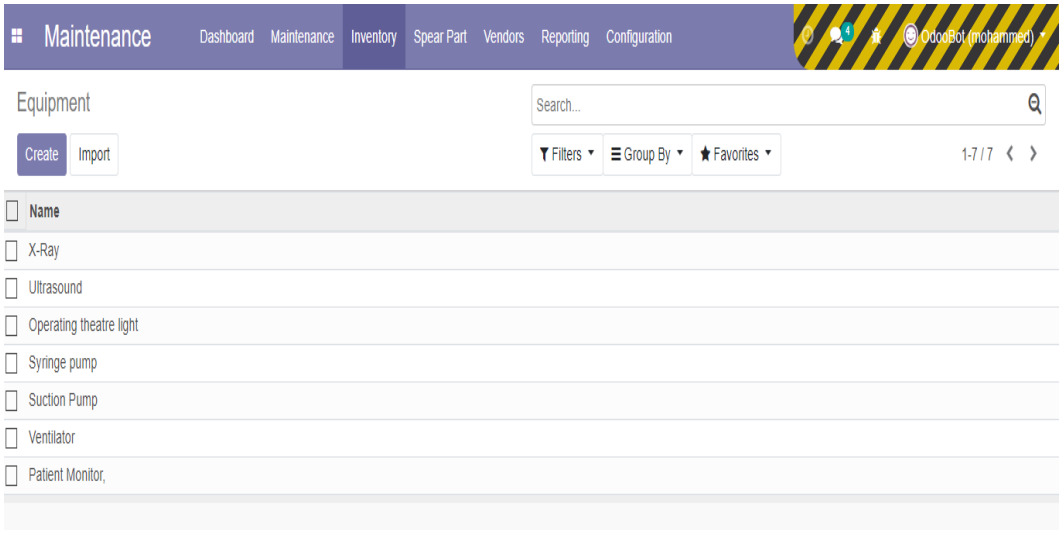

Figure (4-7): Equipment list page

Every health-care facility has different requirements for the information about each equipment that needs to be included in an inventory. In this system, information is divided into sections as appears as a figure (4-8).

Gernal Information:

it has information about the name and categorizes, identification number Unique identifier for each piece of equipment Medical equipment, operating status Identifies equipment as “in service” or “out of service”, Physical location within a health-care facility Includes room number or department; allows medical equipment to be located when preventive maintenance is due and Department ownership details Identifies point of contact for notification in service delays, and to schedule preventive maintenance.

Manufacture Information:

it has information about Manufacturer Identifies the company that makes the equipment, Serial number Unique identifier of the equipment, Model Unique identifier of the product line and Year of manufacture Used to calculate the age of the equipment; used with expected equipment lifetime as an input to determine when an item needs to be replaced, retired or discarded

Purchases Information:

Purchase supplier Used as a point of contact regarding the purchase, reorders, warranty replacements, Purchase cost Serves as an input to capital inventory values and for budgeting purposes All Purchase date In the case of capital assets used to calculate depreciation values or replacement obsolescence determination. In the case of parts, may be used to determine usage rates, reorder requirements and expiration dates and Year of manufacture Used to calculate the age of the equipment; used with expected equipment lifetime as an input to determine when an item needs to be replaced, retired or discarded.

Dates

it has information about Date the equipment was entered into the inventory and the last date the information was updated, Warranty expiration date Useful in tracking warranty validity and expiration, Installation date and acceptance testing information and results Serve as a foundation for the service history record and are used as a reference when troubleshooting, Expected equipment lifetime Lists the expected amount of time (typically in years) that a piece of equipment may be safely and effectively in service; may be used as an input to determine when an item needs to be replaced, retired or discarded.

Maintenance Information

It has information about Outlines frequency of preventive maintenance intervals and procedures for maintenance, Operating and service history May include user or maintenance logbooks (for operation or service), work order or service record and this section is automatically updated after any maintenance procedure.

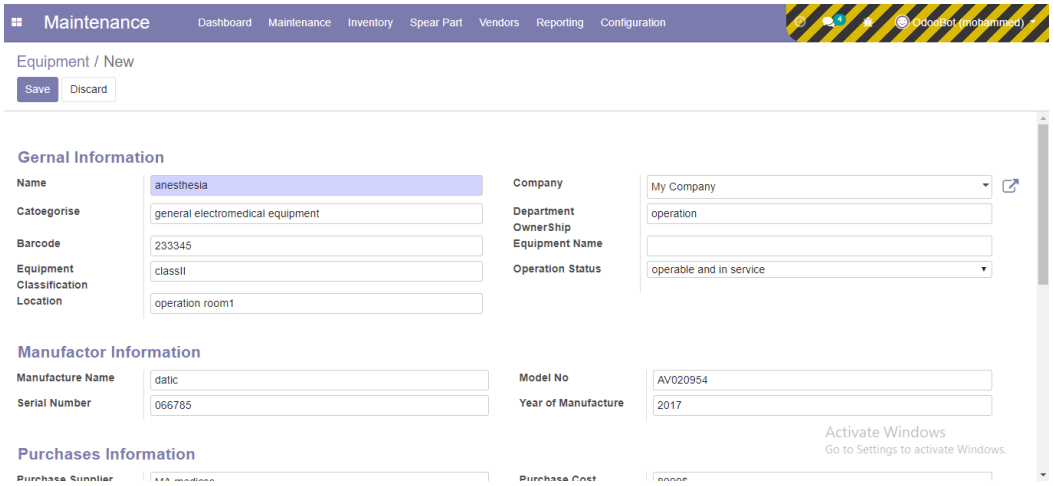

Figure (4-8): Creation equipment page

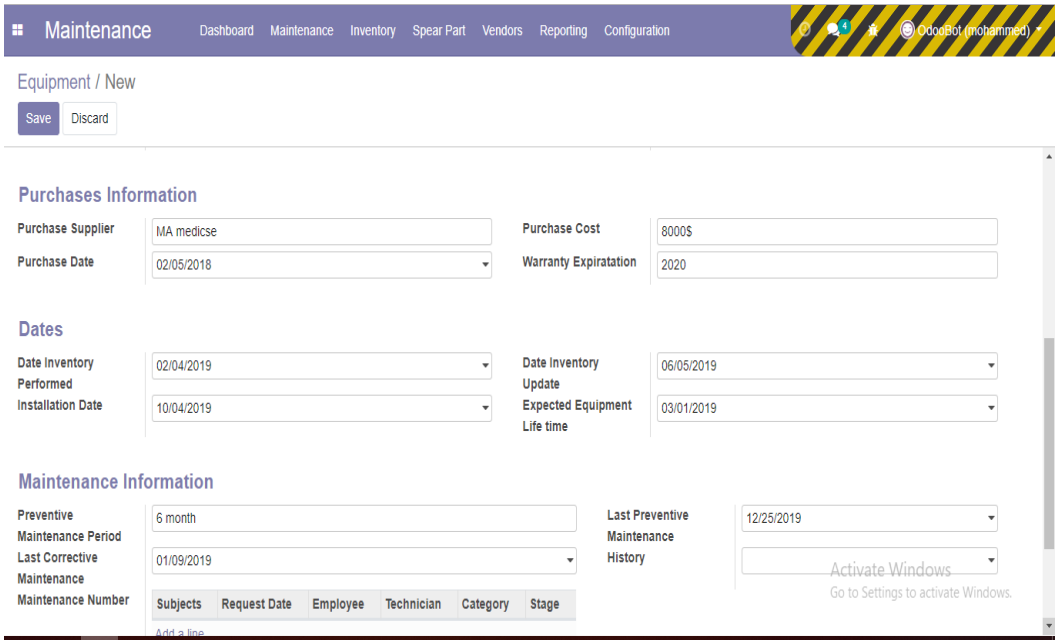

Figure (4-9): Creation equipment page

after save, the user can edit any information about equipment by clicking on edit in the equipment profile and can delete or duplicate the equipment by clicking on the action, and print maintenance report as PDF include information about maintenance procedures are done that show at the figure(4-9).

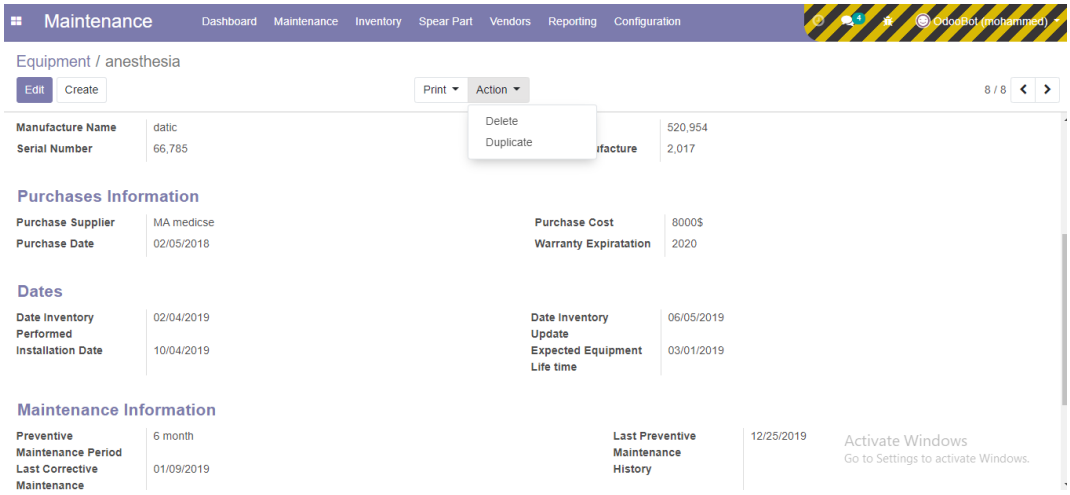

Figure (4-10): equipment profile page

- **Spar parts inventory**

The spare parts inventory is an extension of the equipment inventory module that tracks the spare parts related to equipment and helps to maintain stock levels. Stocked parts include those that are common to a number of different pieces of equipment. The system can alert the user to minimum stock levels for particular parts, create reports regarding the frequency of part replacement, which can help with predicting maintenance schedules and future stock levels, list all the parts required for certain pieces of equipment, report on the consumption of reused parts

- **create new spar part**

can add new spar part by clicking create in the main screen of spar part inventory screen and this screen shows the list of all other spar parts as appears as a figure (4-11).

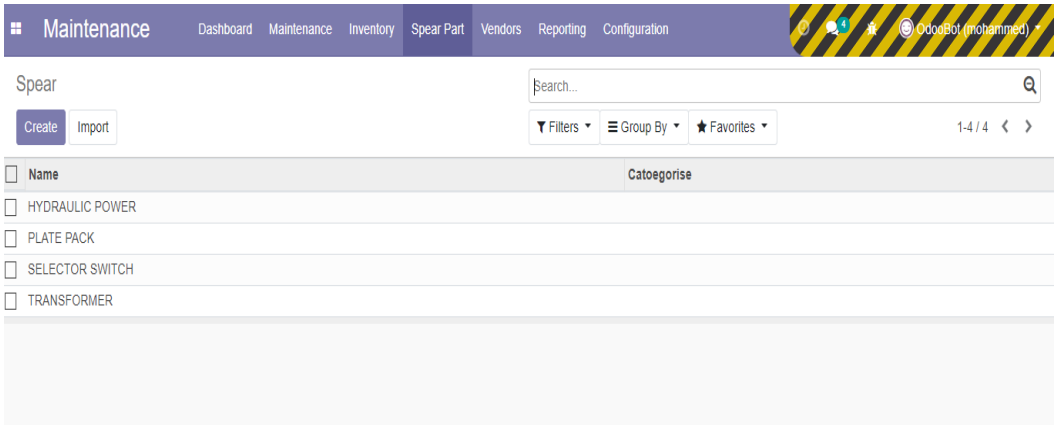

Figure (4-11): Spare parts list page

Fields in the spare parts inventory might include:

Part description (name) , stock (inventory) number , manufacturer's name, serial and part number, link to equipment model, minimum stock level, current stock level, part storage location, price and date purchased as appears as a figure(4-12).

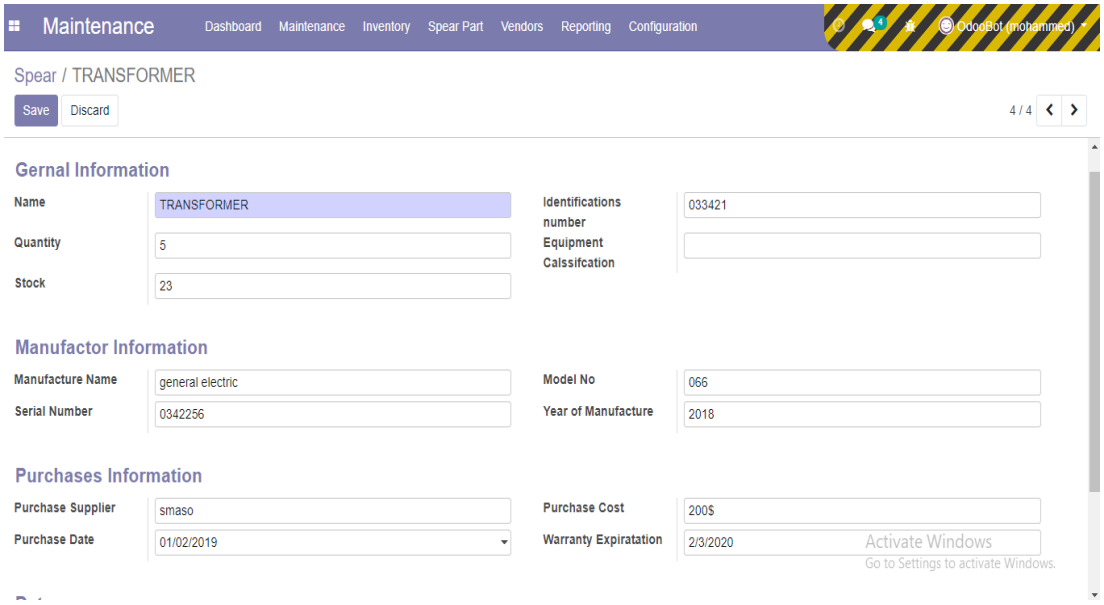

Figure (4-12): Creation spare parts page

after save, the user can edit any information about spare part by clicking on edit in the spar part profile and can delete or duplicate the spar part by clicking on the action that show at the figure(4-13).

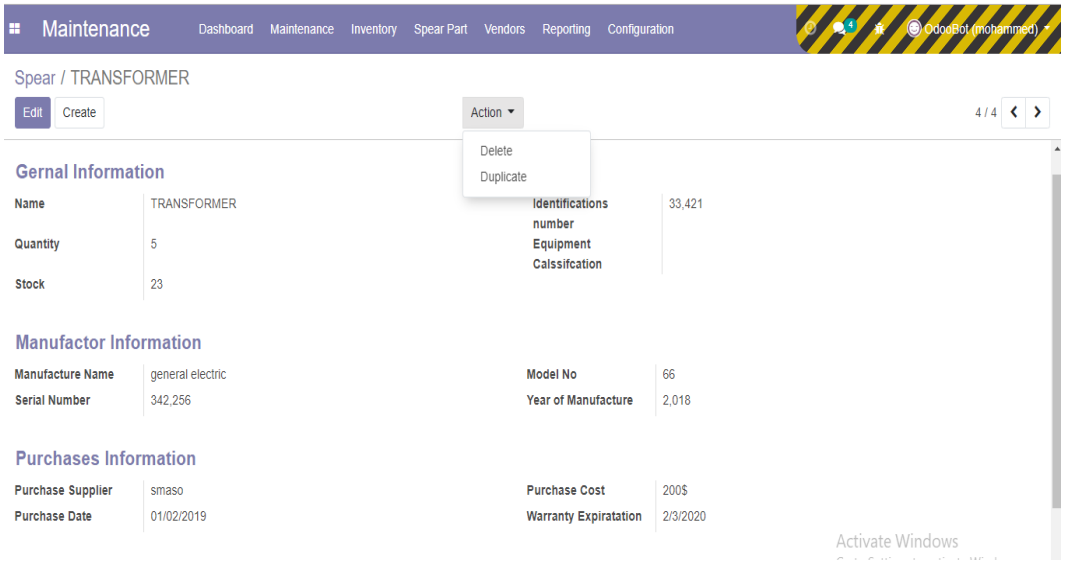

Figure (4-13): Spar parts profile page

- **Maintenance Module**

Maintenance module it has the ability to Keep track of past service event (e.g. PM, CM, recalls, software updates, etc.) and retrieve or print them if needed, Store PM procedures and related information, Schedule PM procedures, change the schedule of PM procedures and print a summary list of what has been scheduled, Print individual PM forms with the appropriate procedure, the past few service events (for reference), and the expected PM completion date/ time, Record and store the results of the PM, Record the CM activity including the problem with the device, time spent in the repair process, a description of the work done and the list of parts used, Produce summary reports of PM completion rates, PM that failed and required repair work, PM actual versus expected completion times

Dashboard

Here can track all Maintenance Requests for each Maintenance team, for example, shown in the figure (4-14), the system has one Maintenance Request scheduling with the top priority it should do by the internal maintenance team.

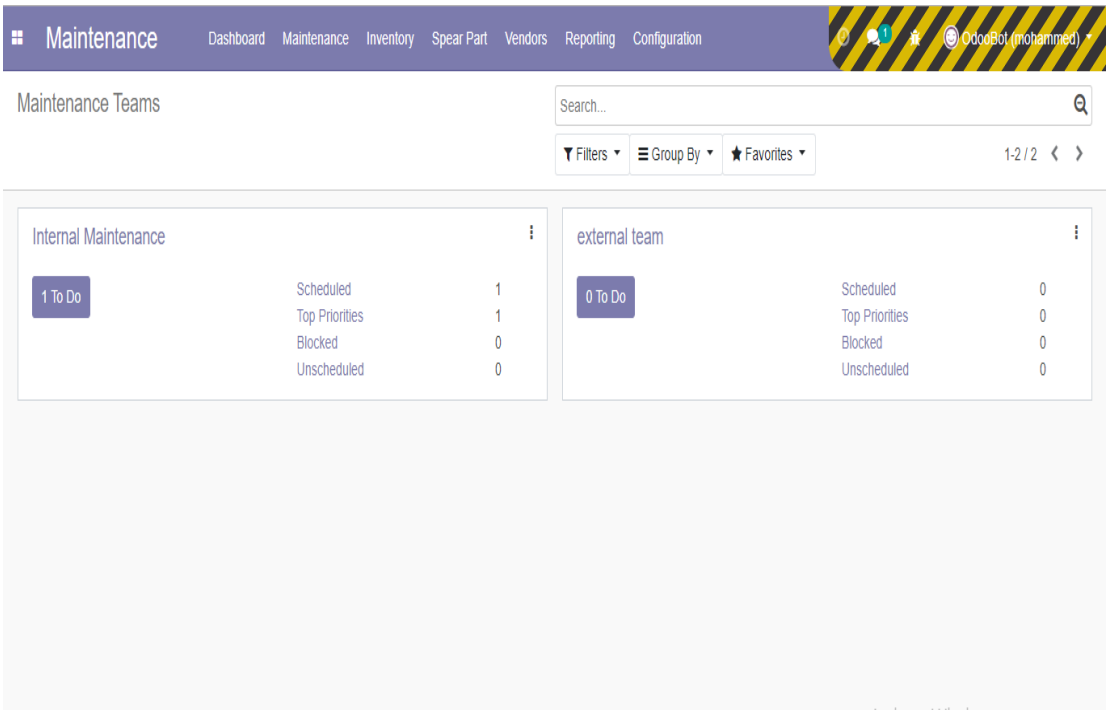

Figure (4-14): Dashboard page

- **Maintenance team:**

In order to establish an organized and systematic up keeping of equipment, we need a maintenance team. On the receiving of maintenance requests that are created, the team take necessary actions for the same. One can create maintenance team via adding the following information:

> *Team name*

> *Team members*

For example, as appears as in figure (4-15) creating an external team with has two member

To create maintenance team, **Configuration -> Maintenance Teams -> C reate.**

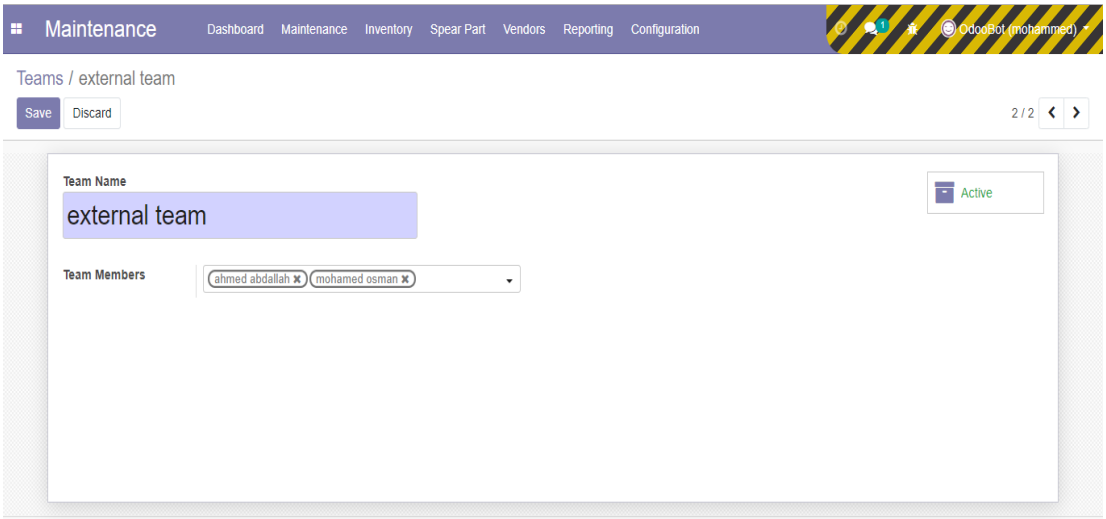

Figure (4-15): Creation Maintenance team page

- **Maintenance request**

One can create a maintenance request from the maintenance module as sh own in Figure (4-16).

Go to **Maintenance ->Maintenance request.**

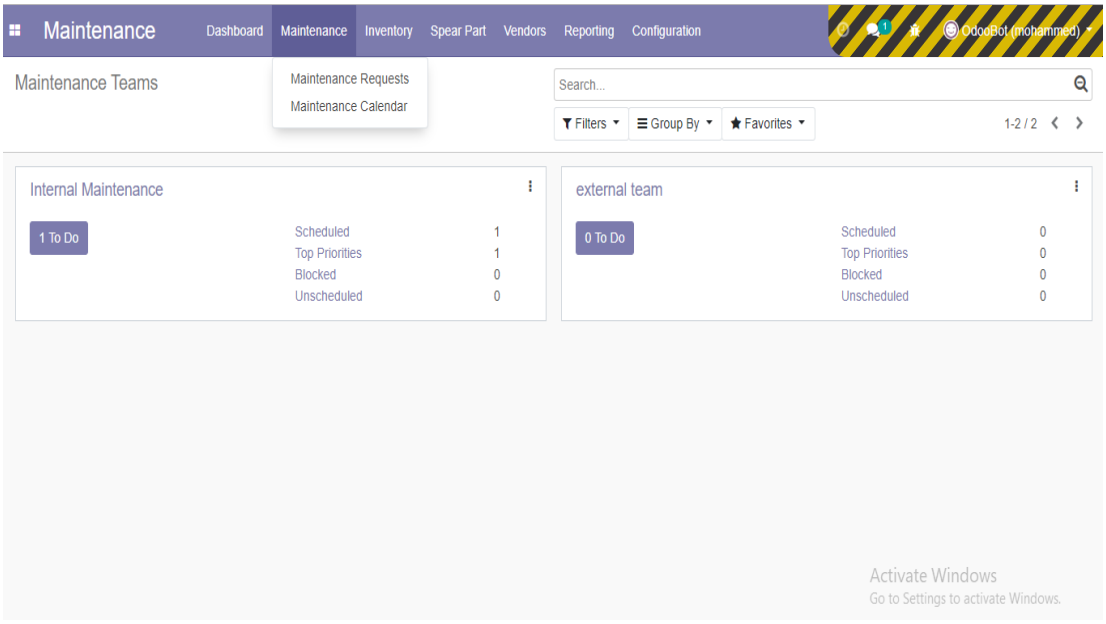

Figure (4-16): creation Maintenance request page

Name: One can give a name for the maintenance request.

Created By: Employee who create maintenance request.

Company: Company that request for maintenance.

Equipment: Choose the equipment for maintenance.

Request date: The date on which maintenance request is created. It will b e generated automatically by the system.

Close Date: Date on which maintenance is completed.

Maintenance type: Maintenance is of 2 types, Corrective and Preventive. Preventive maintenance is the maintenance support that is carried on an e quipment before its failure. In other words, it is the servicing of an equipm ent carried in regular intervals. Corrective maintenance is the maintenance support carried on an equipment upon its failure. It is simply the correctiv e measure against the failure.

Manufacturing order: When equipment failure happens in between man ufacturing order, one can choose the manufacturing order here.

Teams: Choose a maintenance team for maintenance

Responsible: Responsible person of the maintenance request.

Scheduled date: Date on which the maintenance team plans the maintena nce. It should not differ much from the requested date.

Duration: Duration of maintenance.

Priority: Priority can be set to a maintenance request.

Spar part: if is need of spar part as shown in Figure (4-17).

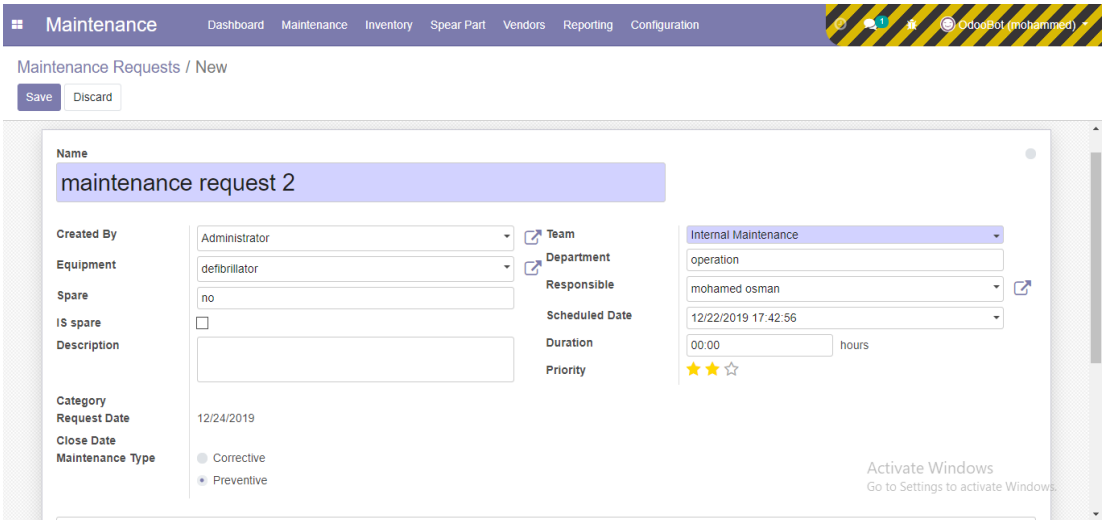

Figure (4-17): Maintenance request page

After save the request maintenance the administration can send the request with a message and can attach any file like equipment manual and engineer can receive this request in email or by discuss module as shown in Figure (4-18).

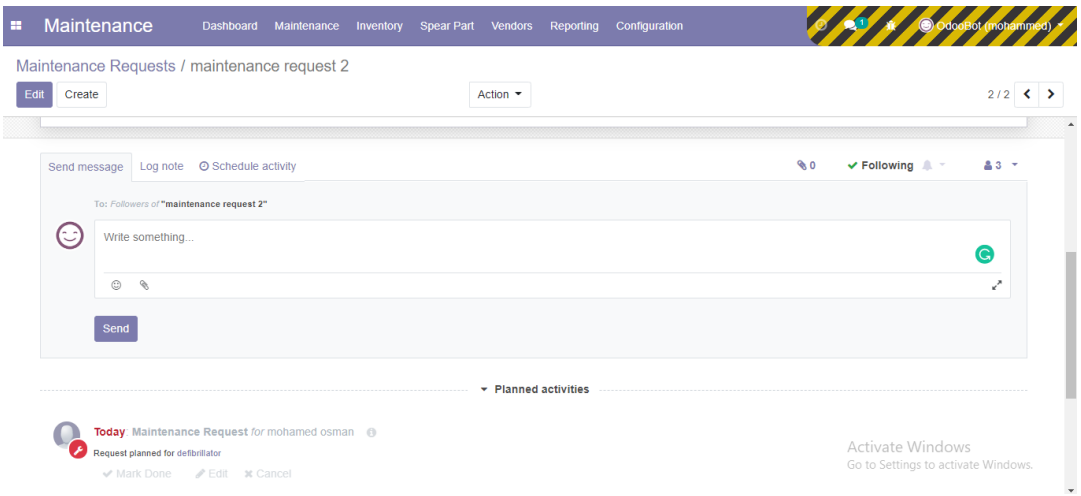

Figure (4-38): Maintenance request page

Meanwhile, the maintenance team can update the stages of the request such as:

> New Request

> In Progress

> Repaired

> Scrap

The team can manage these support stages in a pipeline

Once the maintenance is in progress, the state gets changed to INPROGRESS. Once the equipment gets repaired, the state automatically gets changed to REPAIRED. If the equipment is scrapped, the state gets changed to SCRAP. Once the state is repaired or scraped, the close date will be automatically added as shown in Figure (4-19) , figure (4-20).

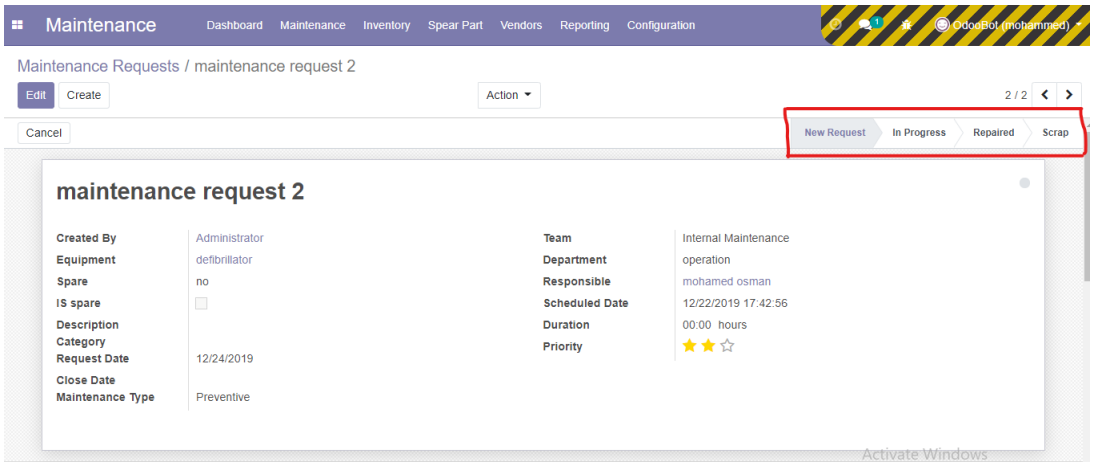

Figure (4-19): Maintenance request page

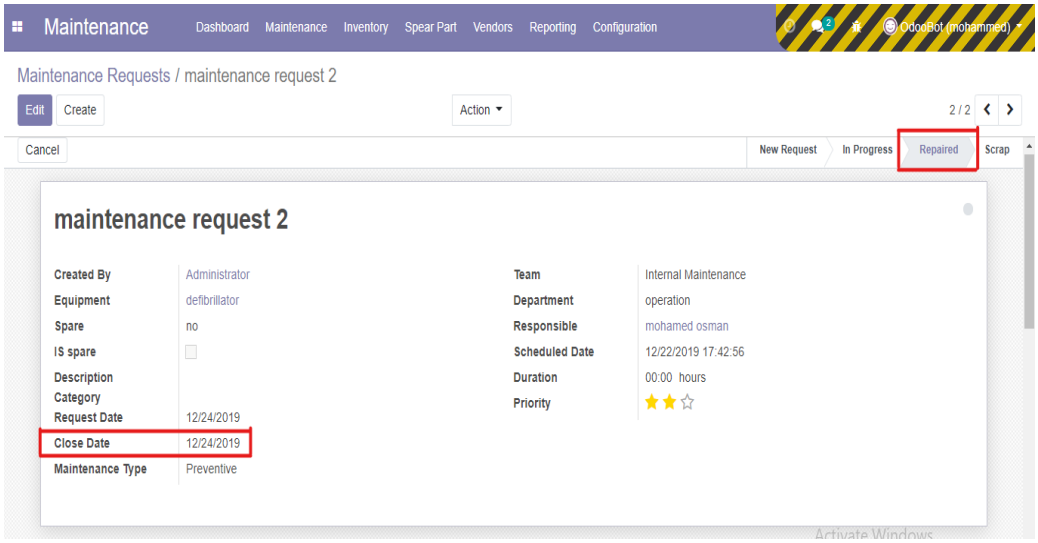

Figure (4-40): Maintenance request page

- **Maintenance Calendar.**

One can easily view or add the new maintenance request from Maintenance Calendar. Calendar Format helps in quick glance of maintenance request created, making sure no requests are pending or unattended. Using the Maintenance Calendar, the teams can schedule themselves in prior, also set target say week/month to complete the task as shown in Figure (4-21). For that go to **Maintenance -> Maintenance Calendar**

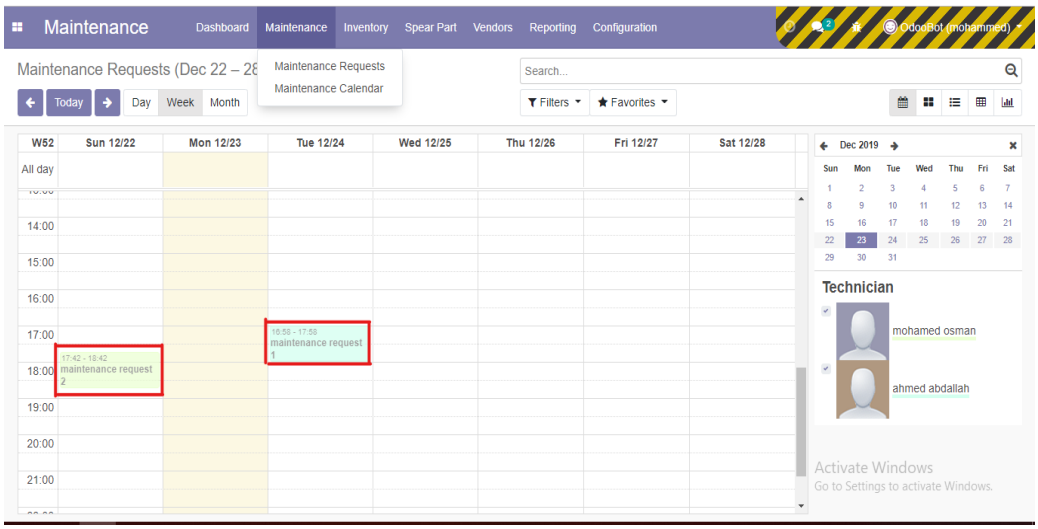

Figure (4-21): Maintenance Calendar page

Here, one can choose the date and create a maintenance request.

For that click on a date -> edit as shown in Figure (4-22).

It will take to create a maintenance request, which it had explained above.

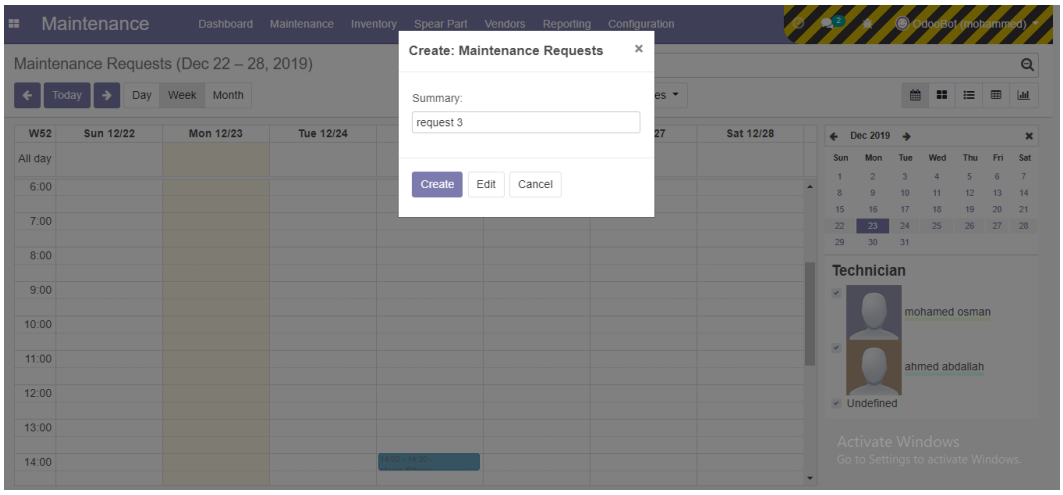

Figure (4-22): creation a maintenance request at maintenance calendar page

- **Maintenance Reports**

The created maintenance requests for various equipment is made visible in different report kind in Odoo.

- Graph view displaying various data.
- Pivot view displaying data like equipment category, department, employee.
- Kanban view displaying pipeline view of the maintenance requests as shown in Figure (4-23).

  For example, report show the relationship between assigned technician and stages of maintenance request such as New Request, In Progress, Repaired as shown in Figure (4-24).

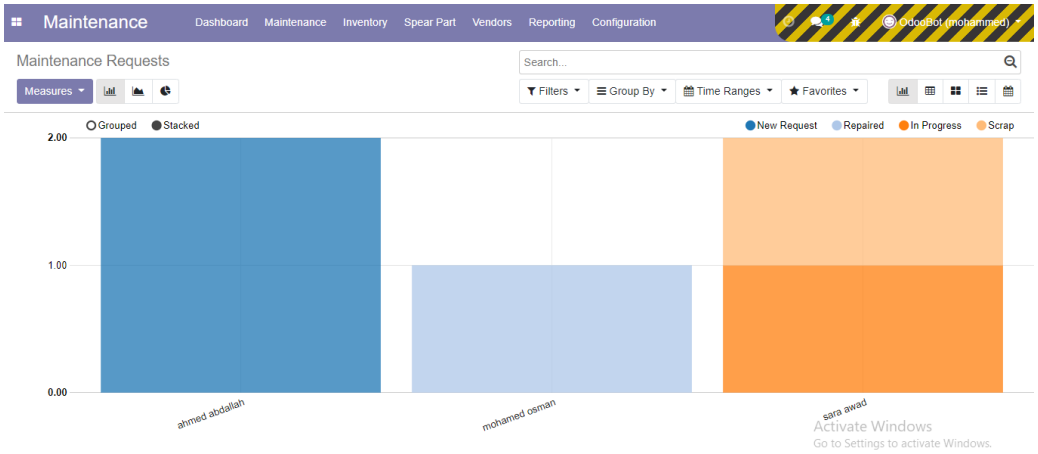

Figure (4-23): Maintenance Reports page

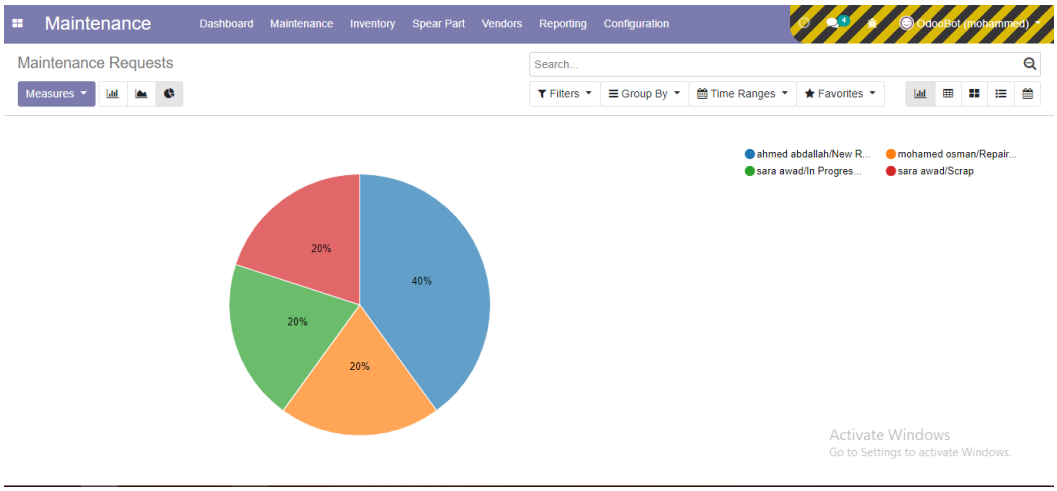

Figure (4-24): Maintenance Reports page

The system has the ability to count and analysis between any information like equipment, employee, maintenance type, etc. for example figure (4-25) shows the number of corrective and preventive maintenance for each equipment.

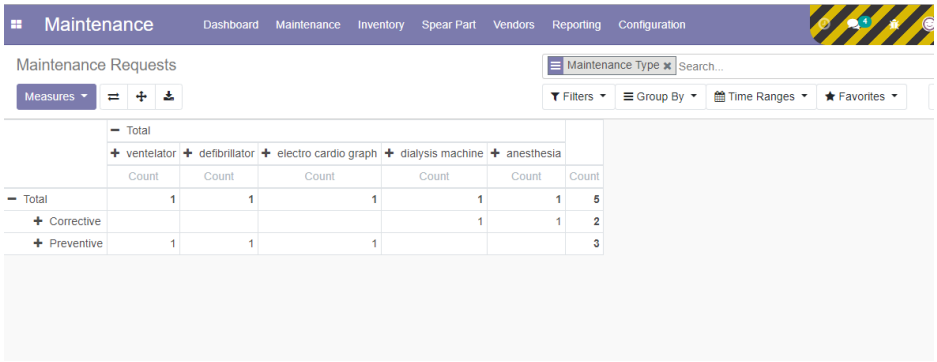

Figure (4-25): Maintenance Reports page

- **Employee Module**

Odoo Employee Module is one such application that intuitively looks after the employee management operations in CED. Odoo Employee module is feature-rich and can be customized to any degree making it perfectly pitched to need. It serves as a scalar application making it highly seamless and highly efficient to monitor and manage employees from different office locations. Also alongside the module helps with supervision of employee work reports, employee performance, track their work hours and so on. Under the employee module, one can enter details of the employee as well as their salary structure and employee contract. Likewise, one can easily locate the department employee works in, and enter their private information. The module thus helps in quick identification of the employee that too in a hierarchical structure based on the employee's employment status

- **Create an Employee Profile**

Can assign a user to an employee by Clicking on the **Create** button will bring up the form to begin entering a new employee into Odoo as shown in Figure (4-26).

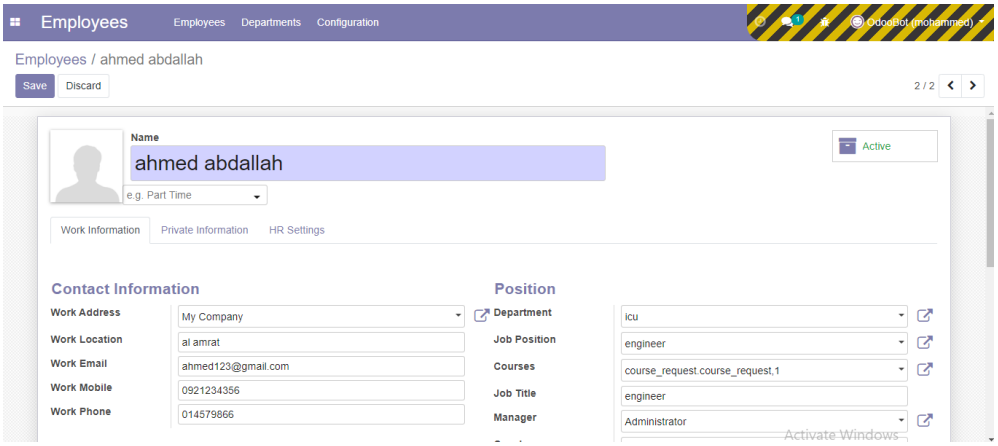

Figure (4-26): Employee Profile page

The only required field in the employee form is Name. All the other fields are optional. Odoo will default the working address to the company address. While most fields are self-explanatory.

Work information section it has details about contact information and position of the employee in CED.

private information has information about status, Citizenship, Birth, Work Permit, Education and can add all document related to employee that show in figure(4-27).

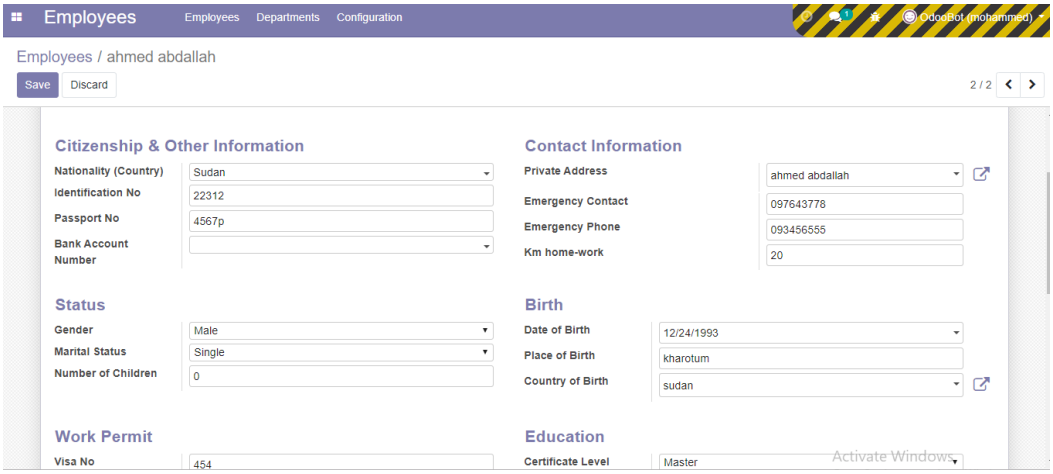

Figure (4-27): Employee Profile page

- **Discuss module**

Odoo 'Discuss', as the name indicates it is a module which facilitates effective communication among different users of the Odoo ERP. It simplifies the communication between colleagues, clients or any person in the organization. The discuss has the facility to manage Group and private chat for better, organized communication. This application is integrated with all other modules in odoo, which means the user can initiate chats from any module as shown in Figure (4-28).

- **Manage Message Inbox**

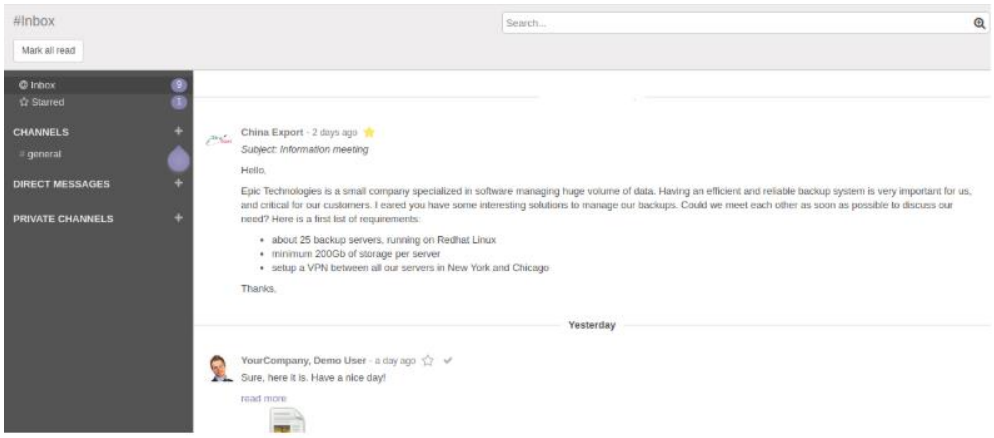

Figure (4-28): Message Inbox page

- **Manage Channels**

There will be a default channel ‘general’, this channel is accessible to all users and can be used to share CED information.

The user can create a new channel by clicking on the + button in the ‘CHANNELS’ menu as shown in Figure (4-29).

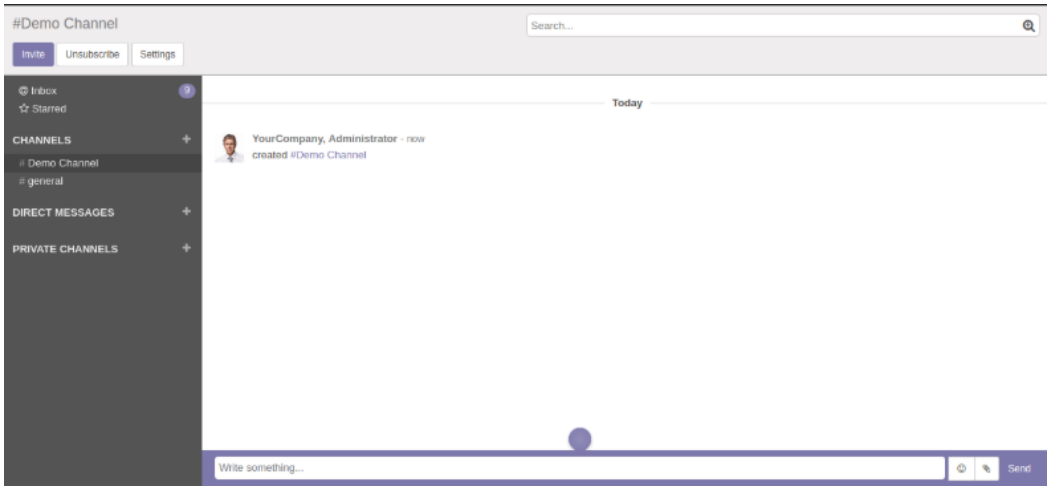

Figure (4-29): Channels page

Can add more people to the channel by clicking on the Invite button as shown in Figure (4-30).

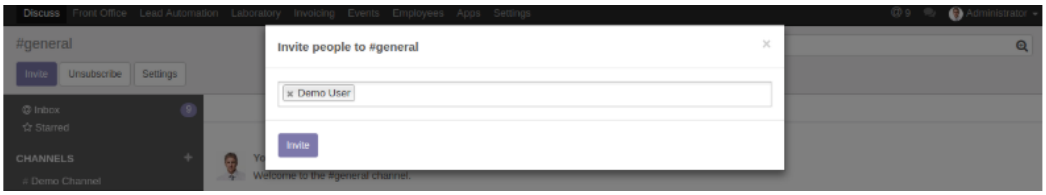

Figure (4-30): Invite user to channel page

Add the users to the box and click invite.

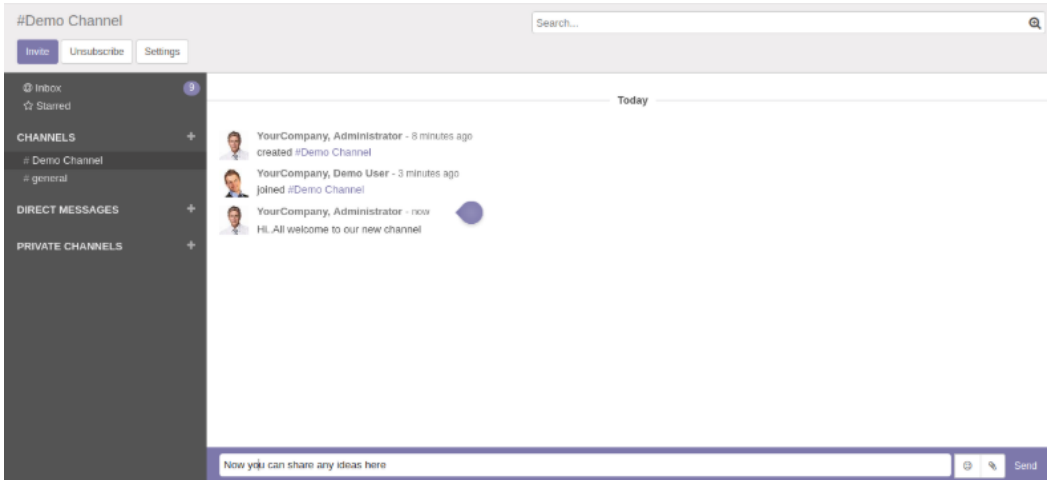

Figure (4-31): Invite user to channel page

Once added people to the channel, can start communication. Can share any images, video, text files to the channel by clicking on the attachment button as shown in Figure (4-31).

CHAPTER FIVE

DISCUSSION

As health facilities expand and the number of medical devices they depend on to provide quality health care increases, a need to manage health-care technology more effectively and efficiently becomes evident. A computerized maintenance management system is a tool that can improve overall medical equipment management at the facility level.

A prototype system has been designed by using "ODOO" formerly known as Open source Enterprise Resource Planning (ERP), Implemented requires proceeding through a number of phases that allowed the system to be planned comprehensively. By completed this multistep process, the options for deployment evaluated; suitable modules were selected, installed and customized and data was entered.

The creation of an inventory list served the need for identification and control of all medical equipment in the hospital. The integrated system assisted in optimizing the use of the available technology and further uses the inventory as a central node for monitoring, training, quality and cost control, and the assignment of tasks and allocation of responsibilities with regard to medical devices. Connecting the equipment inventory with all system functions permitted flexible access and easy retrieval of information related to all aspects of a medical device's life cycle.

The CED plays a major role in the decision-making process with regard to the replacement of old technology and the acquisition of new medical equipment. These decisions should be based on information about safety, reliability, quality, and cost. Information on equipment failures and downtime, detailed records on maintenance and repair activities, and the costs associated with them, all of which are provided by the system,

assisted the CED in establishing priorities and replacement planning. The system also provided qualitative indicators on support services and other factors, such as insufficient technical support, delays in service contractor response, and excessive spare part costs that contribute to decision making about maintenance policy or replacement of existing technology.

CED staff monitoring is a major priority for CMMS to ensure efficient use of equipment; to reduce incidents and risk of user errors, and to increase patient safety. This resulted in optimized department performance and productivity, significant cost savings, and higher efficiency of equipment use. The system also monitored and analyzed indicators that reflect the services provided by the CED on a daily basis. These indicators assess many different aspects of CED performance and provide an overview of the technology status in the hospital. This can reveal possible factors for quality and efficiency improvements, thereby leading to subsequent corrective actions. Reports and statistical analysis are the tools used to monitor and collect quality data.

The system offered advantages because of its separate software modules and flexible data-exchange communication. The separate modules and submodules offer narrow serviced differentiation and detailed medical device management, complete documentation, and explicit data analysis. The daily evolution of technology leads to new management tasks and their necessary and timely implementation in practice. Therefore, the system provided possibilities for expansion by creating new peripheral modules.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion:

Computerized maintenance management system is a biomedical equipment management tool, addressing the demands of a rapidly changing health care environment and the broader role that CEDs must play. The system can expand its functions, thanks to its separate software modules, to handle more managerial tasks, the broad use of the CMMS improved the effective management of medical equipment with significant benefits related to cost-efficiency and safety. The system assisted CEDs in organizing their services and managing their resources in a more efficient way, Much less staff time is needed for data entry, maintenance tracking and reporting; it minimized human errors; and it allowed more effective monitoring of performance indicators and staff productivity. The CMMS provided electronic documentation of equipment inventories, repairs, and maintenance and equipment histories. It can be used as an effective tool by health facilities and their clinical engineering departments to complement their existing programs and improve the overall management of the technology, while also contributing to the more effective delivery of health care.

6.2 Recommendations:

After designing of the prototype computerized maintenance management system , fulfilling of some objectives that shown in the system results, there are many points that recommends to do in future works in order to go ahead to extend the idea and achieve real solutions in management clinical engineering department:

- It is recommended to train all staff of clinical engineering department to use the computerized system and other technologies.
- It is recommended to increase the system flexibility by adding it to smart phones of biomedical engineers as an application and connect between the systems by internet networks.
- It is recommended to extend this system in the future to include barcode module in Odoo which enables the end-user to creation Barcode nomenclatures and scan the barcodes to get the details of medical equipment and spare part that saved in inventory.
- It is recommended to develop the system in the future by adding a manufacturing module that helps diagnose malfunctions that appear on medical devices.

REFRENCES

[1] Bronzino, “Handbook of clinical engineering”, CBC press, 1995.

[2] https://www.who.int/medical_devices/full_deffinition/en/

[3] Sharareh Taghipour, “Reliability and Maintenance of Medical Devices”, Department of Mechanical and Industrial Engineering, University of Toronto, pp 6-23, 2011.

[4] http://healthfinder.gov . (28/6/2011).

[5] http://www.ncbi.nlm.nih.gov . (1/2/2012).

[6] http://www.hc-sc.gc.ca . (1/6/2011).

[7] https://www.ebme.co.uk/articles/management

[8] Joel Levitt, complete guide to predictive and preventive maintenance second edition, Industrial Press New York, library of congress cataloging in publication data, 2005.

[9] Wang, Feng, Zhanmin Zhang, and Randy B. Machemehl. "Decision-making problem for managing pavement maintenance and rehabilitation Projects", Transportation Research Record: Journal of the Transportation Research Board 1853. 1, pp. 21-28, 2003.

[10] IAPA ,“Industrial Accident Prevention Association”, preventive maintenance, in May 2007, pp.553-121.

[11] James B Fink, “Device and Equipment Evaluations, Respiratory Care”, Respiratory Care Journal symposium, The ABCs of Research at the

49th International Respiratory Congress, in Las Vegas, Nevada. Vol 49 No 10, PP: 1157–1164.2004.

[12] J. Tobey Clark, Michael Lane and Leah Refuse, Medical Equipment Quality Assurance: Inspection Program Development and Procedures, Instrumentation & Technical Services, University of Vermont -280 East Avenue Suite 2 Burlington, Fluke Biomedical. 2009.

[13] World Health Organization, Computerized maintenance management system, L'IV Com Sarl, Villars-sous-Yens, Switzerland, WHO Library Cataloguing-in-Publication Data, 2011

[14] Cohen T et al. Computerized maintenance management systems for clinical engineering. -Arlington, Association for the Advancement of Medical Instrumentation, 2003.

[15] Francisco J. Acevedo, Jose E. Fuentes, John D. Ederle, "Design of Computerized Maintenance Management System for the Chilean Naval Hospital Biomedical Engineering Department", University of Connecticut,2005.

[16] N. Medhat1, S. A. Samy2, M. Abdel Wahed2, A. S. A. Mohamed2,''MEDICAL EQUIPMENT QUALITY ASSURANCE FOR HEALTHCARE FACILITIES'', Biomedical Engineering Department, Faculty of Engineering, Minia University, Egypt, 2008.

[17] W.S. Trarawneh, A. Ghawanmeh, I. Malkawi1 and M. Ghannam," Quality Assurance and Control of Clinical Engineering Activities" Directorate of biomedical engineering, Ministry of Health, Amman, Jordan, 2008.

[18] Chia-Hung Chien*, Yi-You Huang, and Fok-Ching Chong,'' A framework of medical equipment management system for in-house clinical

engineering department'', Department of Biomedical Engineering, National Taiwan University Hospital, Taipei, Taiwan, 2010.

[19] CĂLIN CORCIOVĂ, MARIUS TURNEA, RADU CIORAP - Risk Management for Medical Devices, Department Biomedical Science, (10/1/2011).

[20] Waleed M. M. AL-Talabi, Amr Sharawi, ''Quality Management System for Medical Devices A field study of the reality of some Arab countries'', Faculty of Engineering, Cairo University, October, 2012.

[21] David Mutia , John Kihiu , Stephen Maranga, Maintenance Management of Medical Equipment in Hospitals,Department of Medical Engineering, Mombasa Polytechnic University College, Mombasa, Kenya.

Appendices

Odoo Architectural

- Models and Modules

Modules: folder contains all files with diffrent type on code or porgramming language

Models : folder contains all file with main language in odoo python is main language

Odoo used python in main code means how system playing and any fuctions what, when and where used;

XML is programming language but nor dynamic just used to show fuctions operations and some type of repotrs ;HTML,CSS and JavaScript used in screens generally Json used for any operations by internet with server.

Demo code:

```
<?xml version="1.0"?>

<odoo><data>

<!-- -->

<!-- <record id="object0" model="alfeel_hospital.alfeel_hospital"> -->

<!-- <field name="name">Object 0</field> -->

<!-- <field name="value">0</field> -->

<!-- </record> -->

<!-- -->
```

```
<!-- <record id="object1" model="alfeel_hospital.alfeel_hospital"> -->
<!-- <field name="name">Object 1</field> -->
<!-- <field name="value">10</field> -->
<!-- </record> -->
<!-- -->
<!-- <record id="object2" model="alfeel_hospital.alfeel_hospital"> -->
<!-- <field name="name">Object 2</field> -->
<!-- <field name="value">20</field> -->
<!-- </record> -->
<!-- -->
<!-- <record id="object3" model="alfeel_hospital.alfeel_hospital"> -->
<!-- <field name="name">Object 3</field> -->
<!-- <field name="value">30</field> -->
<!-- </record> -->
<!-- -->
<!-- <record id="object4" model="alfeel_hospital.alfeel_hospital"> -->
<!-- <field name="name">Object 4</field> -->
<!-- <field name="value">40</field> -->
<!-- </record> -->
<!-- -->
</data>
```

Maintenance report code

```
<?xml version="1.0" encoding="UTF-8"?>
<odoo>
    <template id="report_maintenances_heet">
        <t t-call="web.html_container">
            <t t-as="o" t-foreach="docs">
                <t t-call="web.external_layout">
                    <div class="page">
                        <h2 class="text-center">Maintenances Report</h2>
                        <br/>
                        <br/>
                        <table class="table table-sm">
                            <thead>
                                <tr>
                                    <th>Medical Equipment</th>
                                    <th>Engineer</th>
                                    <th>Scheduled Date</th>
                                    <th>IS Spare</th>
                                    <th>Spare</th>
                                    <th>Department</th>
                                    <th>Description</th>
                                    <th>Employee</th>
                                </tr>
                            </thead>
                            <tbody>
                                <tr t-as="line" t-foreach="o.number_maintenance_ids">
                                    <td>
                                        <span t-field="line.equipment_id"/>
                                    </td>
                                    <td>
                                        <span t-field="line.name"/>
                                    </td>
                                    <td>
                                        <span t-field="line.schedule_date"/>
                                    </td>
                                    <td>
                                        <span t-field="line.take_spare"/>
                                    </td>
                                    <td>
```

Inventory module code:

```
<?xml version="1.0"?>
<odoo>
    <data>
        <!-- formm view definition -->
        <record id="esrra_alfeel.form" model="ir.ui.view">
            <field name="name">New Record</field>
            <field name="model">esrra_alfeel.esrra_alfeel</field>
            <field name="rach" type="xml">
                <form>
                    <group string="Gernal Information ">
                        <field name="name"/>
                        <field name="description"/>
                        <field name="dept_owner"/>
                        <field name="baracode"/>
                        <field name="equip_number"/>
                        <field name="equip_class"/>
                        <field name="condition"/>
                        <field name="location"/>
                        <field name="searil"/>
                    </group>
                    <group string="Manufactor Information ">
                        <field name="name_man"/>
                        <field name="model"/>
                        <field name="country_id"/>
                        <field name="year"/>
                    </group>
                    <group string="Purchases Information ">
                        <field name="purchase_supp"/>
                        <field name="purchase_cost"/>
                        <field name="purchase_date"/>
                        <field name="warranty"/>
                    </group>
                    <group string="Dates">
                        <field name="date_performed"/>
                        <field name="date_update"/>
                        <field name="install_date"/>
                        <field name="expected"/>
                    </group>
```

```
            - <group string="Maintenance Information ">
                <field name="preventive"/>
                <field name="last_pre"/>
                <field name="last_corr"/>
                <field name="history"/>
                <field name="number_maintenance_ids"/>
              </group>
            </form>
          </field>
        </record>
          <!-- explicit list view definition -->
        - <record id="esrra_alfeel.tree" model="ir.ui.view">
          <field name="name">esrra_alfeel list</field>
          <field name="model">esrra_alfeel.esrra_alfeel</field>
          - <field name="arch" type="xml">
            - <tree>
                <field name="name"/>
                <field name="description"/>
              </tree>
          </field>
        </record>
          <!-- actions opening views on models -->
        - <record id="esrra_alfeel.action_window" model="ir.actions.act_window">
          <field name="name">esrra_alfeel window</field>
          <field name="res_model">esrra_alfeel.esrra_alfeel</field>
          <field name="view_mode">tree,form</field>
        </record>
          <!-- Top menu item -->
        <menuitem id="esrra_alfeel.menu_root" name="esrra_alfeel"/>
          <!-- menu categories -->
        <menuitem id="esrra_alfeel.menu_1" name="Menu 1" parent="esrra_alfeel.menu_root"/>
          <!--menuitem name="Menu 2" id="esrra_alfeel.menu_2" parent="esrra_alfeel.menu_root"/> actions -->
        <menuitem id="esrra_alfeel.menu_1_list" name="List" parent="esrra_alfeel.menu_1" action="esrra_alfeel.action_window"/>
          <!--menuitem name="Server to list" id="esrra_alfeel" parent="esrra_alfeel.menu_2" action="esrra_alfeel.action_server"/-->
      </data>
    </odoo>
```

Spare part module code

```
<?xml version="1.0"?>
<odoo>
    <data>
        <record id="spare_hospital_form" model="ir.ui.view">
            <field name="name">spear part</field>
            <field name="model">spare_hospital.spare_hospital</field>
            <field name="arch" type="xml">
                <form>
                    <group col="4" string="Gernal Information">
                        <field name="name" placeholder="Enter Name"/>
                            <!-- <field name="company_id"/> <field name="description"/> <field name="dept_owner"/> -->
                        <field name="baracode"/>
                        <field name="equip_number"/>
                        <field name="equip_class"/>
                        <field name="location"/>
                            <!-- <field name="spare"/> -->
                    </group>
                    <group col="4" string="Manufactor Information">
                        <field name="name_man"/>
                        <field name="model"/>
                        <field name="searil"/>
                            <!--field name="country_id"/-->
                        <field name="year"/>
                    </group>
                    <group col="4" string="Purchases Information">
                        <field name="purchase_supp"/>
                        <field name="purchase_cost"/>
                        <field name="purchase_date"/>
                        <field name="warranty"/>
                    </group>
                    <group col="4" string="Dates">
                        <field name="date_performed"/>
                        <field name="date_update"/>
                        <field name="install_date"/>
                        <field name="expected"/>
                    </group>
                </form>
            </field>
```

```
                    <field name="year"/>
                </group>
              - <group col="4" string="Purchases Information">
                    <field name="purchase_supp"/>
                    <field name="purchase_cost"/>
                    <field name="purchase_date"/>
                    <field name="warranty"/>
                </group>
              - <group col="4" string="Dates">
                    <field name="date_performed"/>
                    <field name="date_update"/>
                    <field name="install_date"/>
                    <field name="expected"/>
                </group>
            </form>
        </field>
    </record>
        <!-- tree view definition -->
  - <record id="spare_hospital_tree" model="ir.ui.view">
        <field name="name">Spear part list</field>
        <field name="model">spare_hospital.spare_hospital</field>
      - <field name="arch" type="xml">
          - <tree>
                <field name="name"/>
                <field name="description"/>
            </tree>
        </field>
    </record>
        <!-- actions opening views on models -->
  - <record id="spare_hospital_action_window" model="ir.actions.act_window">
        <field name="name">Spear</field>
        <field name="res_model">spare_hospital.spare_hospital</field>
        <field name="view_mode">tree,form</field>
    </record>
    <menuitem id="spare_hospital_medical_equipment_menu_act" name="Spear Part" sequence="8" action="spare_hospital_action_wi
        parent="maintenance.menu_maintenance_title"/>
  </data>
</odoo>
```

Employee module code

```
- <record id="view_hr_employee_form_inherit_account" model="ir.ui.view">
    <field name="name">hr.employee.form.inherit</field>
    <field name="model">hr.employee</field>
    <field name="inherit_id" ref="hr.view_employee_form"/>
  - <field name="arch" type="xml">
    - <data>
      - <xpath position="after" expr="//field[@name='job_id']">
          <field name="course_id"/>
        </xpath>
      </data>
    </field>
  </record>
  <delete id="maintenance.menu_equipment_form" model="ir.ui.menu"/>
    <!-- formm view definition -->
```

Vendor module code

```
- <record id="alfeel_vendor_form" model="ir.ui.view">
    <field name="name">Vendors list</field>
    <field name="model">maintenance.vendor</field>
  - <field name="arch" type="xml">
    - <form>
      - <group col="4" string="Gernal Information">
          <field name="vendor"/>
          <field name="request_id"/>
        </group>
      </form>
    </field>
  </record>
    <!-- tree view definition -->
- <record id="alfeel_hospital_tree" model="ir.ui.view">
    <field name="name">Vendors list</field>
    <field name="model">maintenance.vendor</field>
  - <field name="arch" type="xml">
    - <tree>
        <field name="vendor"/>
        <field name="request_id"/>
      </tree>
    </field>
  </record>
    <!-- actions opening views on models -->
- <record id="vendor_menu_act" model="ir.actions.act_window">
    <field name="name">Vendors</field>
    <field name="type">ir.actions.act_window</field>
    <field name="res_model">maintenance.vendor</field>
    <field name="view_mode">tree,form</field>
    <field name="view_type">form</field>
  - <field name="help" type="html">
      <p class="oe_view_nocontent_create"> </p>
    - <p>
        <!-- More details about what a user can do with this object will be OK -->
      </p>
    </field>
  </record>
```