EVALUATION OF THE EFFECTIVENESS OF FACILITIES MAINTENANCE MANAGEMENT IN MAJOR PUBLIC AND PRIVATE HOSPITALS IN KENYA.

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Evaluation of the Effectiveness of Facilities Maintenance Management in Major Public and Private Hospitals in Kenya.

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

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DEDICATION

I dedicate this work to my entire family.

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LIST OF ABBREVIATIONS

CES	Clinical Engineering Service
CMMS	Commercial Computerized Maintenance Management
CNT1	Contractor 1
CNT2	Contractor 2
CST1	Consultant 1
CST2	Consultant 2
CST3	Consultant 3
CST4	Consultant 4
CST5	Consultant 5
ECRI	Emergency Care Research Institute
HSS	Hospital Support Services
KNH	Kenyatta National Hospital
MRI	Magnetic Resonance Imaging
PPM	Planned Preventive Maintenance
PRH1	Private Hospital 1
PRH2	Private Hospital 2
PRH3	Private Hospital 3
PUH1	Public Hospital 1
PUH2	Public Hospital 2
PUH3	Public Hospital 3
PUH4	Public Hospital 4
PUH5	Public Hospital 5
PUH6	Public Hospital 6
PUH7	Public Hospital 7

PUH8 Public Hospital 8

SPSS Statistical Package for the Social Sciences

SPU Sterile processing unit

UDI Unique Device Identification

ABSTRACT

Medical equipment malfunctions and frequent equipment failure are some of the reasons for medical errors which are a leading cause of death and injury among hospitalized patients. Dilapidated medical equipment found in various hospitals may offer substandard healthcare. There are frequent malfunctioning of hospital equipment and the resources for the maintenance processes are scarce. There is a need for effective maintenance for medical equipment in oder to attain manufacturer's specification and clinical requirements. However, little existing literature do not provide answers for the existing problems.

The purpose of the research was to evaluate the effectiveness of facilities maintenance management in major public and private hospitals in Kenya, through the assessment of medical equipment performance and develop an appropriate maintenance program to assist the maintenance management practice and processes. The survey was carried out through interviews using questionnaire. Facility managers from major public and private hospital were interviewed on medical equipment management. Observation technique was also used to provide primary source of data. The data collected from the facility managers was analyzed using histograms where performance weighting was reflected based on medical equipment in hospitals. A combined mean was determined from the performance of equipment to deduce effectiveness of the maintenance organisations in major hospitals in Kenya.

The finding from the analysis of the data collected revealed that the public maintenance organization does not have proper management of the medical equipment. The other facility managers have excellent procedures to coordinate and oversee the safe, secure and environmentally sound operations. They also maintain the hospital assets in a cost effective manner which is aimed at long-term preservation of the asset

value. Poor maintenance and management of equipment have been contributed by lack of spare parts, inefficient technical staff, use of conditional maintenance rather than PPM.

Implementation of the developed maintenance programme shall improve the maintenance management of equipment by creating an up to date inventory system, develop a real time solution on who, how and when to repair the equipment. It is expected that these results will help hospitals, the investors of the hospitals and patients. The hospitals will henceforth become effective through efficiency and reliable medical equipment. The shareholders of private hospitals and the government will benefit on increased revenue through more efficient medical equipment. The patients will benefit through correct diagnosis and hence correct treatment prescriptions saving their lives.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Medical equipment are sensitive devices in which a mis diagnosis or wrong functioning by the equipment may result to adverse effects. The equipment may be used on the patients who are not able to respond to hazardous conditions or pain, some of medical equipment function as life support and their failure may result in the patient's death. Most of the sophisticated and complicated machines found in the intensive care unit, have their electrical connection existing between the equipment and patient.

Medical or Biomedical equipment management is a fundamental part of managing a clinical or biomedical engineering department. It includes the administration of medical equipment involved in the diagnosis, treatment, and monitoring of the patient. The related policies and procedures govern activities from the selection and acquisition through the incoming inspection, acceptance, maintenance, and eventual retirement and disposal of medical equipment.

The medical equipment management professionals ensure that equipment used in the patients care are operational, safe, properly configured and continue to function effectively in a good working condition. Proper maintenance of an equipment can extend its life. Maintenance is therefore, essential for providing good health services and saving the scarce resources. However, in addition to maintenance, medical equipment management involves other essential activities to ensure that equipment is well planned, budgeted and procured. Human factors engineering is used to in-

fluence medical device procurement decisions in hospitals. It ensures that the safest and most efficient economic and effective devices are purchased. Human factors engineering is an important method to reduce medical error and adverse events and to increase patient safety, when it is applied to the design and evaluation of medical devices [2].

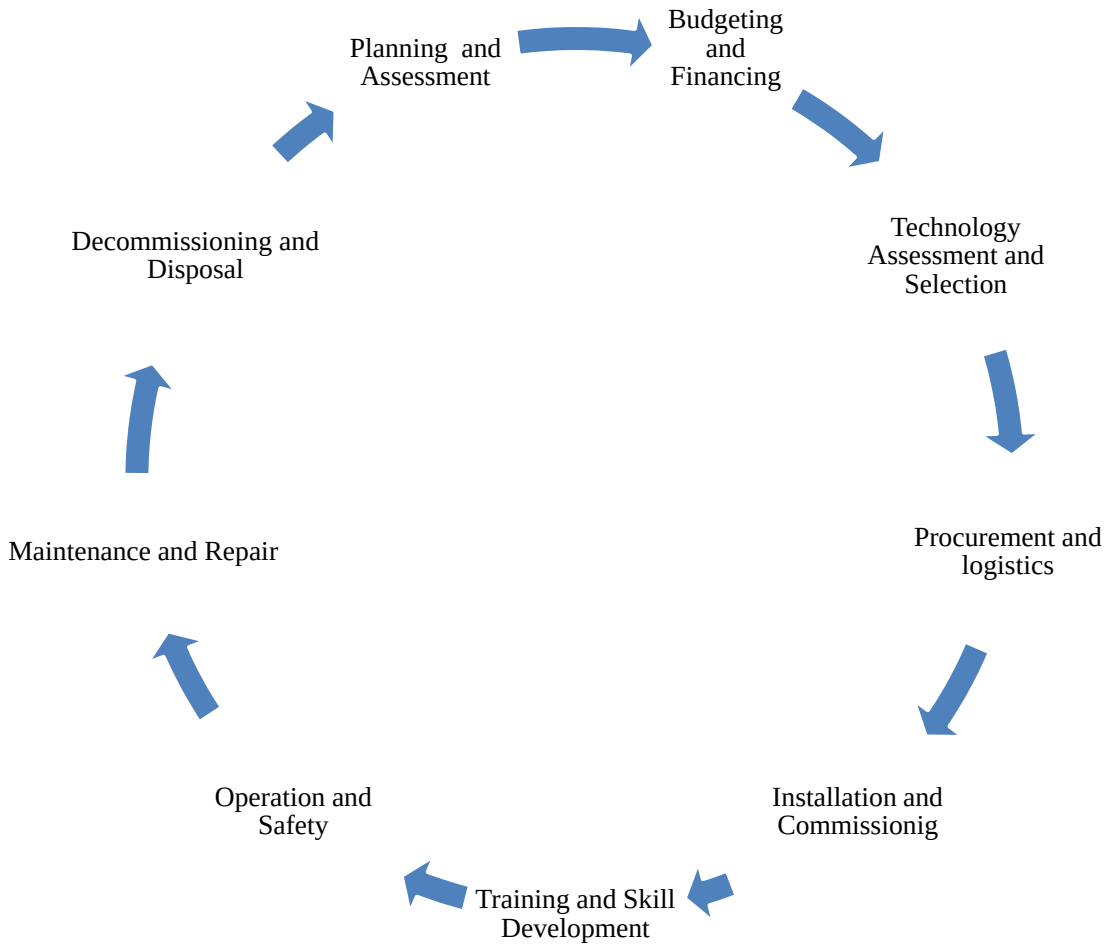


Figure 1.1: Medical equipment cycle [3]

Figure 1.1 shows a cycle of activities in the life of medical equipment [3]. Facilities management is a strategic function and makes a positive contribution to business growth and organization success. It is a diverse profession, of which the main aim is to provide quality environments, which are fit for the purpose of hospital facilities.

It also involves a constant balancing between the competing pressures of time, cost and quality [4]. The process yields a better productivity which means a state of efficiency or the rate and quality of output based on the rate and quality of input [5]. As it relates to hospital facilities management, higher productivity can mean safer and more reliable equipment, less service cost, less equipment downtime, more revenue and more effective use of man power [6]. Hospital and health care facilities are among the most complex, costly and challenging equipment to manage. One of the main challenges of managing hospital facilities is the highly diverse network and range of functions which are needed to maintain operations and the complexity of services which are required to support them [7]. The prime responsibility of the facilities management organization in the hospital is to maintain the fabric and structure of hospital building together with the equipment within the duration of their life cycle. The medical devices life cycle includes the tendering and commissioning of new equipment,the training of staff on their operation and application, performing the necessary preventative maintenance, conducting repairs and finally device disposal. The purpose of these tasks is to ensure optimum performance and to minimize risk to both patients and staff. The medical equipment can be divided into four groups: Laboratory equipment, Diagnostic equipment, Therapeutic equipment, Hospital equipment and other support equipment [8].

1.2 Facility Management Organization

The role of the facility management organization is to coordinate and oversee the safe, secure and environmentally sound operations and maintenance of the hospital assets in a cost effective manner aimed at long-term preservation of the asset value. The facility managers in major hospitals in Kenya use the Planned Preven-

tive Maintenance (PPM) and its concept of Monitoring and Evaluation system to reduce and eliminate unpredicted malfunctions of the equipment, which occur suddenly and therefore cannot be detected or prevented by PPM measures [9]. A great number of equipment faults occurs because of the deterioration of equipment with usage and may be detected prior to their causing a malfunction. The PPM system which is being used in major Kenyan hospitals involves several essential elements which includes; Labelling of equipment which has to be affixed with a unique equipment number for each device, technical documentation, inspection, service schedules and procedures, inventory system which is used to provide consistent, accurate and up-to-date information on the hospital equipment. In monitoring and evaluation, a variety of documents are used: equipment record sheet, request sheet, job card, history card, inspection and service forms etc. Hospitals perform pre-determined services on a particular equipment or perform corrective maintenance on breakdown equipment as shown in Figure 1.2. When equipment require corrective maintenance the request sheet are filled by the user to signal the need for maintenance work on certain piece of equipment. The request sheet carries at least the description of the equipment, its inventory number and the nature of the malfunction.

The hospital or contracted engineer is required to fill up the job card requirements. It has all the information on the maintenance work to be carried out which includes; nature of fault, condition of equipment, parts repaired or replaced, cause of defect, material used and manpower. After the repairs are concluded, the equipment record sheet is obtained. The engineer in-charge is expected to use the information in order to perform the functional and performance test of the equipment. More information of the particular equipment is obtained from both history and stock card if they are available. When predetermined service is to be performed, the hospital or contracted engineers are expected to inspect and study the service schedule due dates for pre-

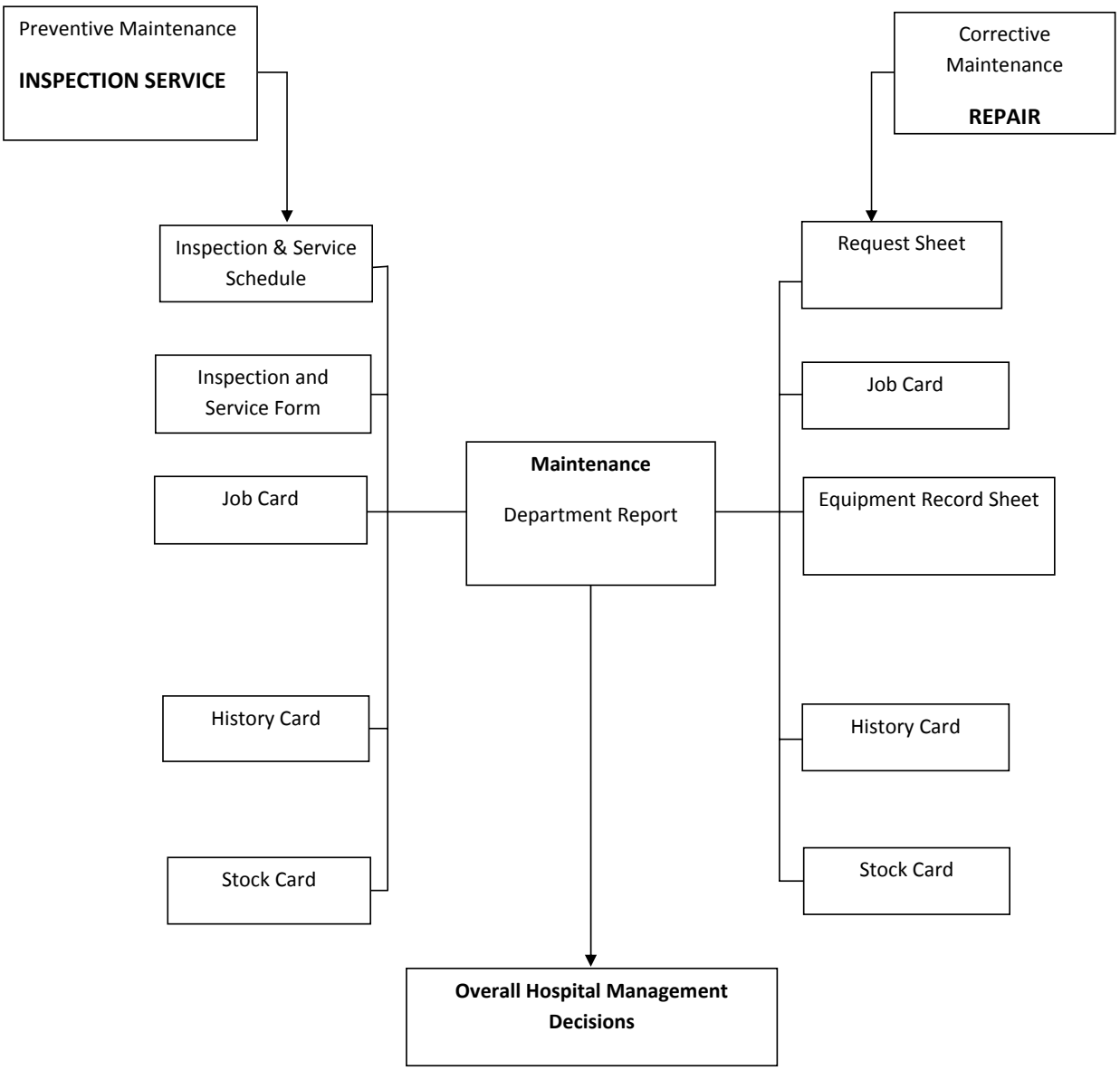


Figure 1.2: Monitoring and evaluation system for medical equipment program

ventive maintenance activities which are marked for the particular equipment. The service procedures describe the task to be performed on the equipment periodically. The engineer in-charge is required to fill up the job card requirements and then perform the necessary services before handing over the equipment to the user. More information of the job activities and particulars of the equipment are found in the history and stocks cards.

The aims on evaluating the effectiveness of the facilities maintenance management in the hospital include; [10]

1. increasing awareness of the maintenance contribution;
2. pin-pointing areas where there are short-falls in the service;
3. measurement of the completeness and integration of the policies;
4. establishing the practice to be introduced or requiring change;
5. to set and monitor maintenance targets;
6. developing an environment for continuous improvement in quality of the maintenance service.

This research project focuses on facilities maintenance organization's performance status, and will offer the hospital's management opportunity to appraise the overall progress being made, seek improvements for increased efficiency and more effective utilization of available resource.

1.3 Maintenance Management Teams

In this study the groups within the maintenance management in a hospital included, the hospital maintenance team, the Consultant and the Contractor.

The hospital maintenance team comprises biomedical engineers and medical equipment technicians who have knowledge of the principles and theories governing the maintenance and repair of medical equipment in order to help solve health problems which include designing or modification of hospital equipment [11]. The biomedical engineers and medical equipment technicians have the ability to repair mechanical equipment such as sterilizers, X-ray tables, operating tables, pressure breathing therapy units, respirator and other mechanical assemblies. The team can install, modify, troubleshoot, maintain, test, calibrate, adjust, overhaul, and repair a wide variety of medical, laboratory, and dental equipment [12]. Biomedical engineers who specialize in bio-materials develop and maintain materials that can be safely implanted in the human body [13]. Engineers who work in bio-mechanic apply principles ranging from physic to biological systems, they develop artificial organs; such as the artificial heart. Rehabilitation engineers help improve the quality of life for people with disabilities [14].

The Consultants are expected to be independent and not associated with suppliers or manufacturers. This approach helps to ensure that comments and advice are based on scientific facts and on professional opinion [15]. Having a good grasp of the market on medical equipment, the consultants are able to procure or give procurement advice once the list of items to be purchased has been completed and issued to them. Most of the consultancy firms operating in Kenya have a link with international suppliers. They play the role of an agent between the suppliers and the hospital. Moreover, after the installation of the equipment and the end of the sale

warrant period the firm may be contracted not only to give advice but also service the equipment. This has led to consultant firms providing biased information on the particular equipment and comprising the quality of health care. The warranties and services which are offered by some of the firms are inadequate. The inadequacies include limited time and parts coverage of warranties, poor workmanship by inadequately trained servicing personnel and lengthy repair times leading to high equipment downtime [16].

There are two approaches to maintenance services, namely, total dependences on equipment manufacturing companies or another third party, and in-house maintenance by the organization technicians. Most of the third parties do not have any direct link with the suppliers. They are contracted on the basis of their professionalism. Most of the supporting equipment like elevators, ambulances and other sophisticated medical equipment are serviced by contracted firms from within or outside the country.

Figure 1.3 represents a typical equipment pyramid of medical equipment. The pyramid shape reflects that simple equipment at level 1 are comfortably tackled by the in-house technician while the complex equipment at level 4 may need specialists either from the manufacturing company or contracted firm. The specialists who are able to repair the complicated equipment are few compared to the in-house technicians who are required to repair a great number of simple equipment in their respective hospitals [17]. The hospital may contract specialists to service some of the complicated equipment and let the technicians service the simple ones.

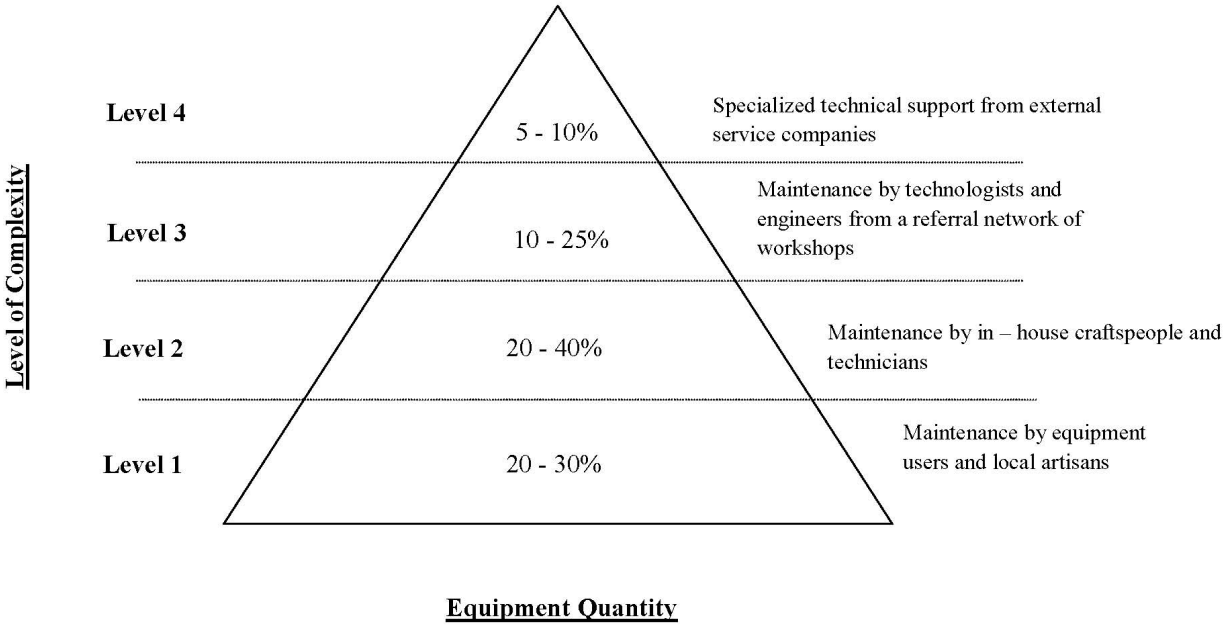


Figure 1.3: Equipment pyramid [1]

1.4 Problem Statement

Medical equipment malfunctions and frequent equipment failure are some of the reasons for medical errors which are a leading cause of death and injury among hospitalized patients. Patient safety is the most critical health care challenge because of hospital medical errors related to biomedical technology management [18]. Many unfortunate cases are caused by misused or faulty medical equipment. The aim of maintenance is to ensure that equipment attains the standard performance characteristics set by the hospital, the manufacturer's specification and clinical requirements. Frequent equipment failure and medical device malfunctions is a sign that the maintenance and servicing programmes have failed. Despite notable improvements in technological standards and rules relating to the design, manufacture and management of biomedical devices, the number of accidents and incidents caused by malfunctions on medical equipment is still on the rise [19]. The research

project seeks to evaluate the existing facilities maintenance management practices and processes in major public and private hospitals in Kenya.

1.5 Objectives

The main objective was to evaluate the existing hospital facilities maintenance management practices and processes in major public and private hospitals in Kenya. To achieve this objective, the following specific objectives were accomplished;

1. to investigate the impact on healthcare in Kenya through equipment maintenance management;
2. pin-pointing areas where there are short-falls in the hospital's maintenance organizations;
3. to find out the causes of hospital equipment faults in major hospitals in Kenya;
4. to help hospitals in Kenya to manage facilities inventory and maintenance of medical equipment;
5. development of a computer maintenance program to assist the maintenance management practice and processes.

1.6 Significance of the Study

All major hospitals in Kenya uses planned preventive maintenance and its concepts of monitoring and evaluation in the maintenance systems. It helps to improve level of equipment performance and safety while extending the equipment life. Unlike manufacturing companies that produce particular goods, hospitals must offer the

highest quality of care possible to their customers, the patients and their families. Although manufacturers must produce high quality products or services, the hospital's failure in quality health care due to poor maintenance of the equipment, can lead to life threatening consequences. To a large extent, physical infrastructure particularly medical equipment determines the coverage, accessibility and effectiveness of health services, and therefore, quality of the entire health system. Unless it is adequately planned, managed and maintained, the health services function cannot be executed in proper way to meet the health needs of the population.

Iatrogenic burns in children are associated with misuse or failure of medical equipment and with mistakes in paediatric medical care [9]. A substantial body of evidence points to medical errors as leading cause of death and injury among hospitalised patients [20]. Sizable numbers of patients are harmed as a result of medical errors. Preventable adverse events among hospitalised patients were reported to be between 3 and 16 percent [21]. Deaths in hospitals, owing to preventable adverse events, may exceed the number attributable even using lower estimates [19] Evaluation on maintenance management provides an appraisal of the organization's maintenance management system and the hospital had to benefit as much as possible from maximum utilization of available technological resources. The research solves many of the problems that might confront patient safety due to medical equipment frequent breakdown inside the hospital.

1.7 Outline of Thesis

This thesis is organized in five chapters. Chapter one is the introduction while chapter two is a literature review on facilities maintenance management practices and processes in public hospital. Chapter three describes the methodology that was

adopted in carrying out the study and the development of the maintenance program. Chapter four results and discussions from the study are recorded. Lastly, chapter five is dedicated to conclusions and recommendations.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview

Hospitals have been faced with a competitive environment which has resulted in the need for increased levels of capital investment to support facilities and equipment perceived necessary to retain top quality physicians. Hospitals have continued to invest capital in tangible, and hopefully billable, equipment in order to retain a public image of being a *State-of-the-art* facility and attract and retain the needed physicians who in turn attract their patients to the hospital that is best equipped [22].

The different approach being used by a number of healthcare facilities includes use of maintenance insurance to minimize costs. The insurance program operates in a simple manner, almost the same way as a service contract. Instead of paying the service contract costs to the manufacturer, to have the same coverage, the hospital now pays the insurance company a premium. During the period of insurance, any expenses resulting from equipment corrective maintenance, preventive maintenance, replacement or loss will be refunded by the insurance company. The biggest disadvantage of this approach is the amount of time spent in management intervention. The maintenance teams from the hospitals are required to coordinate with the vendors, supervise field service monitoring, claim processing and reimbursements monitoring and adding or removing equipment from program [23].

Medical equipment maintenance in a pre-determined state ensures the operation, quality, safety of the health equipment and plant are attained in order to support the provision of satisfactory health care. The maintenance programme ensures that resources are used economically to contribute to the sustainability of health services.

However, when medical equipment does not work properly, blame for the resulting complication should not be directed at clinicians only. The manufacturer and the technical support personnel are at least equally responsible. The extensive utilization of complex and sophisticated electromedical equipment by medical personnel who have little technical background, however, has not only facilitated physicians in diagnosis, prognosis and treatment of disease, but has also caused problems that are new to the world of medicine [24]. A study conducted in Harvard University reveled that nearly four percent of hospitalized patients sustained medical treatment-related disabling injury. Technical causes were the third most common type of the adverse events [25].

Emergency Care Research Institute (ECRI) has historically employed five broad categories which are at the heart of all medical errors involving a medical device [26]. These broad ECRI categories are device factors, user errors, external factors, tampering and sabotage, and support system failures [27]. Equipment failure can trigger an accident or it may complicate the recognition and treatment of other problems [28]. The equipment failure itself may occur due to a variety of causes, such as equipment defect, improper set-up or maintenance, or environmental factors. The problem in the device itself occurs during manufacture also errors in the equipment may be detected after the devices are distributed worldwide [29].

2.2 Case Study on Medical Equipment Failure

In an Iranian hospital, a 48 year old man with left hand paresthesia and weakness lasting five years had to be operated. During the surgery the wound site temperature raised progressively leading to a grade two burn in a five by five centimetre area. The burns emerged as an iatrogenic complication of the operation. Investigator

revealed that the problem was a faulty bulb in the operation room. When the light was dismantled,it was found that the 110 volt lamp had been changed to a 220 volt unit. After 50 years of life, the original unit had become obsolete. Additionally, the glass covering the lamp was broken. The high voltage lamp produced a considerable amount of heat, which was transferred to the operation site owing to the broken glass, resulting in a significant rise in temperature at the focus point of the mirror sited on patient's elbow [30].

Iatrogenic burns in children are quite rare and are associated with accidents in the process of paediatric treatment and care. They are most frequent in operating theaters and consist of both electrical and chemical burns. These misadventures are due to misused or faulty medical equipment. Also frequent are the thermal burns that form the biggest aetiological group in the neonatal period. These are usually the result of hot water scalds when a baby is bathed after birth or else they occur because of faulty hot-water bottles [9].

ECRI has investigated different incidents caused by equipment malfunctioning in either diagnosing or therapeutic process. For instance the institution investigated a case in which a five year old male patient was fatally crushed beneath the pedestal-style electric bed in which he was placed upon admission to the hospital. The accident occurred when the boy was playing with or accidentally operated the beds walk-away down control, which caused the bed to continue to descend even after the control switch was released [31]. Another case involved incorrect placement of a positive end-expiratory pressure (PEEP) valve in the inspiratory limb of an anaesthesia circle system.

2.3 Status of Medical Equipment in Kenya

Not all medical equipment have an expiry date. Indeed, equipment may be used until repairs are no longer possible. Patients suffering from kidney failure have been in trouble following the breakdown of a dialysis machine at the Nyanza Provincial Hospital [32]. It is important, therefore, that original parts are available so that the facilities maintenance organization can use the correct parts when repairing or ordering devices [30]. The Minister for Medical Services had to explain why cervical cancer radiotherapy equipment at Kenyatta National Hospital has been inoperative for the past four years [33]. The East Africa Standard media reported that Kenyatta National Hospital had been burdened by obsolete equipment some of which never worked from the time they were purchased; that is, if they were installed at all. For instance the embalming machines, three X-ray machines, Sterile processing unit(SPU), Laundry equipment and dental facilities are among a huge portfolio of non-functional equipment [34].

The sorry state of cancer treatment was revealed by the Nation Media Group in Nyanza Provincial General Hospital where the branchytherapy equipment used to treat cancer, was revealed to be laying dormant. For the last six years, most Kenyan cancer patients had to seek treatment outside the country, enduring lengthy travel and incurring huge expenses in the process. But it is not that treatment is not available in the country; specialized brachytherapy equipment capable of destroying cancer cells in the early stages had been lying idle both at Nyanza Provincial General Hospital and Kenyatta National Hospital [35]. The brachytherapy equipment for the Nyanza General Hospital was acquired in 1998 by the government at a cost of Sh30 million and was installed in 2002.

The equipment at Kenyatta Hospital was installed in 2001; it was yet to be used.

As the equipment at Kenyatta National Hospital gathered dust for unclear reasons, Nyanza General Hospital had incurred huge costs through repairs and counter-repairs of their equipment. The provincial hospital had flown in teams of engineers several times from the Netherlands, where the brachytherapy equipment had been sent for repair [35].

The article ***The eyesore that is Kenya's hospitals*** exposed the sorry state of government hospitals. The report revealed deplorable condition of facilities that can barely cope with emergencies and could not adhere to clinical guidelines. The audit conducted by Ministry of medical services established scores of hospitals have failed to live up to their billing, raising questions about the safety of patients [36].

The rate of medical equipment induced complications may be lowered by evaluating apparatus using standards such as IEC 60601-1 during the design process and production. The IEC60601-1 standard covers all general requirements for all electrical medical-based products. Equipment surveillance is also important in order to reduce unpredicted malfunctions; maintenance and repair is another aspect that should be also considered to reduce unwanted complications [37].

2.4 Status of Research on Maintenance Management

In 2008 - 2009, a benchmarking study of operation and maintenance costs of French healthcare facilities was carried out [38]. The benchmarking method in France allowed health facility managers in France to evaluate and develop operational strategies, with a view to reducing the costs burden. The investigation presented findings using quantitative methods, including cumulative frequency and descriptive statistics. The authors found that cost per bed ratio could be used as an efficient metric to

classify health facilities into data sets. The results also showed that the operational costs of utilities, maintenance, operations and maintenance staff correlate positively and significantly with the square meter of floor area. However, it was found that the relationship between the total of operational costs per square meter with the floor is negatively correlated and surprisingly only explains 41 per cent of the performance of the health asset operational cost variation in the data sample [38]. A case study on benchmarking for maintenance management in a large-scale power plant was analyzed in the year 2000 [39]. Benchmarking is used to search for optimum methods for maintenance management practices in order to improve the overall effectiveness of the operations and maintenance of the plant. By adopting the best practices appropriately, the research could help plants to become more cost-effective in maintenance. However, for plants looking for breakthrough improvement in maintenance, on top of benchmarking, other means, i.e. intelligent decision support system (IDSS) for maintenance, are required as well [39]. A study was established on professionalisation in hospital management in order to control hospital expenditure and improve the efficiency, management and role of hospitals in the health sector [40]. It was felt that no other investment in health-care facilities by the state can be more cost effective than investment in the development of professional hospital administrators [40]. In 2007, medical waste management practices of a hospital in Southern Africa was examined [41]. A case study methodology was utilised. The results revealed that the hospital does not quantify medical waste. Segregation of medical waste into infectious waste and non-infectious waste is not conducted according to definite rules and standards. Separation of medical waste and municipal waste is however practiced to a satisfactory extent. Wheeled trolleys are used for on-site transportation of waste. Off-site transportation of waste is outsourced to a private firm. Incineration is used in the final disposal of infectious waste. Non-infectious waste is disposed

using land disposal method. There is no policy and plan in place for managing medical waste. A number of problems were identified with respect to medical waste management [41]. Recommendations to enhance the operating efficiency of the hospitals with regards to medical waste management included hospitals to institute an efficient Sharps Management System. A proper equipment and containers at all sharps generating points, a secure accounting and collection system for transporting the contaminated sharps for treatment and final disposal and the proper training of hospital staff on the handling and management of sharps [41]. In 1999, a model was established to determine whether to schedule preventive maintenance and the model trades off the capital costs of preventive maintenance, the sum of corrective maintenance and down-time costs based on the production line's state [42]. In the finding one of the main problem revealed was when choosing between preventive or corrective maintenance for the production and maintenance departments in the eight firms studied, was to attempt to establish the state of a particular production system or individual production line [42]. In 2006, a framework that could identify and evaluate the effectiveness of a given maintenance strategy in a company was established. This could help in the strategic management of maintenance [43]. The framework was developed using Hayes and Wheelwrights four-stage framework on manufacturing strategy as a guideline. The scope of the research was limited to performance measurement of maintenance strategies. It was found that the framework was applicable and useful for the strategic management of the maintenance function [43]. In 1997, an audit assessment of the facilities maintenance management in a public hospital in Malaysia was carried out. The purpose of the research was to assess the existing facilities maintenance management practices and processes in public hospital, in accordance with the concession agreement, in order to identify the current performance status. The government of Malaysia took the initiative

to implement this major privatization project for the provision, maintenance and management of hospital support services (HSS) of public hospitals throughout the country [44]. Three concession companies were selected to undertake research on a total of 123 hospitals and four health institutions throughout the entire country making a total of 127 hospitals, on a fixed price and period basis.
The tool used was a questionnaire which was based on the following:

1. Standards and guidelines in managing the environment of care as stipulated in Juran Institute (1998) Management of environment of care standards.

2. Concession Agreement, hospital support services (HSS) privatization project.

3. Requisites, determined as necessary from the experience of the assessors, in order to provide effective management of facility engineering maintenance.

Reviews were conducted to assess five key elements: Leadership policies, service performance, supervision, training and orientation. The findings of the research described the status of facilities maintenance management in the hospitals under study to be having a good planning and management with all essential requirements and compliance with regulation. However, the research on audit assessment was not able to develop and implement comprehensive and systematic policies, plan and procedures of facilities management through a maintenance management program. This is because the main objective of the research was only to identify the maturity level of the maintenance organization in specific hospitals with regard to the effectiveness of their management of facility engineering maintenance services. The result from the research suggested that the maintenance organization in the case study hospitals had still not realized the importance and effective maintenance management. It was apparent from the research findings that the maintenance organization had not

made much effort to accomplish their roles and responsibilities towards successful implementation of facility engineering maintenance services.

Research on strategic management of technology in public health sector was conducted in Kenya and South Africa in 1999-2000. The main objective was to investigate factors contributing to health care equipment problems and associated technological investments in public hospitals [16]. The research reviewed the processes of equipment planning, procurement and management in ten public equipment maintenance institutions. Fifty six questionnaires were mailed to target technology managers, clinical/medical engineers and technicians in public hospitals in Kenya and South Africa. Thirty eight equipment maintenance experts participated in the survey where majority of them were drawn from teaching hospitals. The research results showed that the way health technology is managed in health care institutions directly affects the quality of treatment the patients receive [45]. Despite the strategic importance of technology in health care being documented widely in scientific literature; equipment planning, procurement and management have not received the attention they deserve in the transformation of health care service in the two countries under the survey [16].

On the basis of the results of the research,recommendations were proposed:

1. Hospitals need equipment assets management systems for monitoring equipment life-cycle costs, maintenance costs and management of equipment replacement.

2. There is need to strengthen and streamline management of technical infrastructure for health care equipment selection, procurement and maintenance management.

3. To achieve optimum utilization of expensive equipment, specialized depart-

ments in public hospitals, such as radiation therapy, radiology, nuclear medicine and renal units, should be permitted to provide specialized technological services to private patients to generate funds for equipment maintenance.

2.5 Commercial Computerized Maintenance Management

Commercial computerized maintenance management systems are used by clinical engineering departments in European hospitals to collect, store, analyze and report data on the repair and maintenance. The systems have become complex database management tools that, for most clinical engineering departments, are too costly and time-consuming to internally develop, update and maintain [46]. FastMaint maintenance management software is a type of a commercial computerized maintenance Management Software. FastMaint can create different calendars that can be used to help manage maintenance schedule. For example the engineer could have two different maintenance teams - one that works at night and the other by day. In the night team's calendar, the night team may start work at 8 pm every night and finish the next day early in the morning at 5 am. The systems deal mostly with the work plan in the maintenance department. The task involves planned preventive and unplanned task.

In 1992, the Clinical Engineering Service(CES) at the Children's Hospital *Bambino Gesu* of Rome, Italy (an approximately 700 bed medical facility) chose to develop its own computerized electromedical equipment management system [24]. This was a tool for decision making in electromedical equipment acquisition strategies, with the aims of minimizing the cost/benefit ratios, and assuring safe and calibrated device. The program output evaluated maintenance costs and workload increase from new equipment installation and compared similar equipment from different manufactur-

ers during pre-purchase evaluation.

CMMS provide capabilities to store retrieve and analyze information. Fernandez et al. [47] proposed a maintenance maturity grid to support the CMMS implementation. Leger and Movel [48] dealt with computer-aided integration of maintenance in an enterprise. Older works include a paper by Singer [49] that discusses a seven-step plan for using all the features of the CMMS package. Two important papers in the area of CMMS include a paper by Labib [50] that uses a formalized decision analysis approach based on multiple criteria and rule-based system for finding the worst machines. This policy emphasizes the fact that the best policy is the one, which improves the life cycle profit. Swanson [51] provides information regarding the characteristics and use of CMMS and also literature review of CMMS. Jones and Collis [52] present findings of a questionnaire survey examining use of computers in maintenance management and concludes that computers are still not optimally utilized and there is considerable potential for future development. Wickers [53] presents a method called Front end maintenance analysis which has widely been applied in industry and proved to be an effective method of identifying parameters for condition monitoring and clearly shows the link between these parameters and a maintenance management system.

2.6 Medical Equipment

Medical equipment have become an important component of modern health services. Table 2.1 shows lists of essential medical equipment under different groups of hospital facilities. The equipment are divided into four group; Laboratory,Diagnostic, Theraupetic and Hospital equipment. Laboratory equipment refers to the various tools and equipment used by nurses and scientists working in a laboratory. Lab-

oratory equipment is generally used to either perform an experiment or to take measurements and gather data. Medical laboratory equipment automates or helps analyze blood, urine and genes. Diagnostic equipment includes medical imaging machines, used to aid in diagnosis. Examples are ultrasound and MRI equipment. Therapeutic equipment aids in curative technique. The equipment provides therapy that cures disease or relieves pain. The equipment includes shortwave diathermy, branchy therapy equipment, resuscitation equipment among others. Medical monitors also assists in the patients treatments by allowing medical staff to measure a patient's medical state. Monitors may measure patient vital signs and other parameters including ECG, EEG, blood pressure, and dissolved gases in the blood. Hospital equipment and other supporting facilities ensures that medical equipment operate effectively and also the patients receive desired services. The hospital equipment includes oxygen plant, electrical generator, refrigerator among others.

2.7 Summary

The available literature shows the way medical equipment is managed in health care institutions directly affects the quality of treatment patients receive. The research on audit assessment of the facilities maintenance management in public hospitals in Malaysia identified the maturity level of the maintenance organization in specific hospitals with regard to the effectiveness of their management of facility engineering maintenance services. It was not able to develop and implement comprehensive and systematic policies, plan and procedures of facilities management through a maintenance management program. It was apparent from the research findings that the maintenance organization had not made much effort to accomplish their roles and responsibilities towards successful implementation of facility engineering main-

Table 2.1: Medical Equipment

Laboratory Equipment

Microscope	Cell counters.
Autoclaves.	Analytical balances.
Centrifuges.	Incubators.
Water bath.	Flame photometers.
Water purification systems.	Photometers.

Diagnostic Equipment

Diagnostic X-ray.	Ultrasound Equipment
Blood pressure machines.	Fluoroscopy.
Electrocardiograph machines and cardiac monitors.	Phonocardiography.
Electroencephalograph.	Electromyography.
X-Ray Computed Tomography (CT Scanner).	Magnetic Resonance Imaging.

Therapeutic Equipments

Cardiac Pacemakers.	Operating theater lamp.
Shortwave diathermy.	Surgical diathermy machine.
Ultrasonic therapy machine.	Anaesthetic equipment.
Resuscitation Equipment.	Ventilators.
Infant Incubators.	Branchytherapy Equipments.
Defibrillators Machine.	Dialysis machine.
Dental unit and Dental chair.	Suction pump.
X-ray therapeutic Machine.	

Hospital Equipment and Other Supporting Facilities

Air Conditioner.	Elevators.
Electrical Generators.	Refrigerator.
Ambulance.	Bed trolley.
Gynaecological Examination table.	Oxygen central plant.
Vacuum plant.	Hospital building.

tenance services. The research on strategic management of technology in public health sector conducted in Kenya and South Africa investigated factors contributing to health care equipment problems and associated technological investments in public hospitals. The research project failed to develop a computer program for monitoring equipment life-cycle costs, maintenance costs and management of equipment replacement. The Clinical Engineering Service(CES) at the Children's Hospital researched on computerized equipment management program which was a tool for decision making in electromedical equipment acquisition strategies and procurement of medical equipment. The program could not determine the possible causes of the medical equipment faults and planned preventive maintenance measures on all medical equipment.

In this research, the objective being to evaluate the existing hospital facilities maintenance management practices and processes, a computer maintenance program has been developed to assist the maintenance organization. It increases awareness of the maintenance contribution and highlights the practices to be introduced or requiring changes in the maintenance management in hospitals. The computer program reduces the use of paper work in maintenance management of the equipment. It assists in equipment acquisition by use of its inventory system and improve on servicing faulty equipment. The program reports the possible causes of the medical equipment faults and the possible personnel to handle the fault in the equipment. The research was able to investigate the impact on health care in Kenya through the equipment maintenance management. It established how facility managers handle the life cycle of the medical equipment. The research pin-pointed short-falls in the hospital's maintenance management.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Introduction

The purpose of equipment management is to ensure that all equipment parts are maintained, in clean, safe and serviceable condition, and are used only by those who have been properly trained and qualified. This is achieved by proper selection of equipment, acceptance of equipment into use, training and certification of selected technical staff, timely servicing and maintenance, disposal and replacement of obsolete or condemned equipment. The research project involved qualitative methods of collecting data. This involved documentation review, interviews via structured questionnaires and direct observations. The objective of the research tools were:

1. **Documentation review:** To find out records of equipment maintenance and management in both private and public hospitals
2. **Questionnaire:** To establish the views of respondents so as to compile accurate findings.
3. **Observations:** To find fast hand information which shall be compared with secondary data.

3.2 Research Design

The major public and private hospitals in Kenya have a bed capacity of 300 and above. They admit and serve a considerable large number of clients. The study was based in selected private and public hospitals in Kenya. The equipment found

and used in these hospitals were used in the study. Several biomedical technicians were interviewed to determine the effectiveness of the existing facilities maintenance management practices and processes in major public and private hospitals in Kenya. Thirty two questionnaires were distributed to the facility maintenance managers in the research institutes, hospitals and other health care companies either as contractors, manufactures agents or suppliers. Eighteen questionnaires were replied out of the thirty two. Those who responded were eight in-house technicians from public hospitals, three in-house technicians from private hospitals, five suppliers and two contractors. In Appendix A, a questionnaire which was used to evaluate the effectiveness of the facilities maintenance management is shown. The questionnaire comprised of seven parameters of equipment life cycle which was adequately answered by the technicians in their respective institutions. The questionnaire has two main parts; Section A and Section B. In section A, the questionnaire defines the goal of the research and outlines the seven main parameters to be interviewed on. In section B, each main parameter has several questions in which the facility maintenance managers were required to answer appropriately. The weighting of each question was tabulated as follows:

- 0 - Very poor
- 1 - Poor
- 2 - Fair
- 3 - Good
- 4 - Very good
- 5 - Excellent

Each question was required to be answered based on the above weighting.

3.3 Programme Development

In this chapter the development of a computer program to assist in the management of hospital facilities is elaborated. In figure 3.1 the maintenance flow chart describes the program development beginning from identification of the category in which the equipment is categorized. The survey conducted majored into four groups each group represented by two types of equipment

- Laboratory equipment; Blood gas and Bacterial incubators
- Diagnostic equipment; Diagnostic X-ray machine, Ultra-sound machine
- Therapeutic equipment; Dialysis Machines, Short-wave machine
- Hospital equipment; Oxygen plant, Autoclaves

The equipment is identified in terms of its category and whether the equipment is in the inventory. This approach reduces accumulation of paper work in the office and proper monitoring of the equipment. The system diagnosis the possible causes with relation to their possible faults in the equipment. It further guides the user to identify the causes of the medical equipment faults and the possible personnel to handle the fault in the equipment. The flow chart shows the system flow of the equipment maintenance management by the three facility managers. The program makes decision on which fault in the diagnosed equipment to be repaired by the supplier, the contractor or the in-house technician.

3.4 Experimental Design

The data collected was introduced into the SPSS program which is a powerful statistical analysis and data management system. Histograms were developed for each of the seven parameters which show the performance weighting versus medical equipment of each question in their respective parameters. The histogram y-axis shows the weighting of the performance while the x-axis shows the medical equipment in their respective institution. The seven parameters analyzed included; technology assessments and selection, procurement and logistics, installation and commissioning, training and skill development, operation and safety, maintenance and repair and decommissioning and disposal. The parameters under study had a minimum of ten questions from which shortfalls in each of the organization were pin-pointed. The histogram had a key which displayed each of the questions on the parameter under study. The combined mean of each parameter was determined. The result was used to compare the effectiveness of the facility managers.

The combined mean rating was tabulated as follows;

Table 3.1: Performance rating

Level	Stage	Rating range percentage
1	Poor	0-20
2	Fair	21-40
3	Good	41-60
4	Very Good	61-80
5	Excellent	81-100

A computer program which guides the user to identify the causes of the medical equipment faults and the possible personnel to handle the fault in the equipment is shown in the appendix B. The codes of the possible faults on the eight medical equipment and their respective causes is also written in the appendix. The medical

equipment maintenance program is written in a C++ program. The advantage of the C++ programming included;

1. It is easier to write a structured program, because complex programming problems are broken into a number of smaller, simpler tasks. Each task is performed by a function in which code and variables are isolated from the rest of the program. Progress can be more quickly when dealing with these relatively simple tasks one at a time.

2. It's easier to debug a structured program. If a program has a bug (something that causes it to work improperly), a structured design makes it easy to isolate the problem to a specific section of code (a specific function).

The program output requests for the name and serial number of the faulty equipment to be entered; ***Enter Machine Name and Serial Number***. Once the equipment name and serial number is entered the program is expected to display the following; *Equipment Name, Category of the equipment, Model No., Supplier Company, Department, Last Serviced Date, Next PPM Date* The program output calls for the fault of the equipment to be entered: ***Enter the Type of Fault***. The program displays the possible causes of the fault in the equipment immediately the request is fulfilled. To determine whether the equipment is under warranty and to be repaired by the suppliers the program displays the following: ***Enter the Serial Number to determine whether the equipment is under warrant***. The program makes decision on which fault in the diagnosed equipment to be repaired by the supplier, the contractor or the in-house technician. The program request the following to be entered: ***Enter the duration in years since the equipment was supplied to the hospital*** .

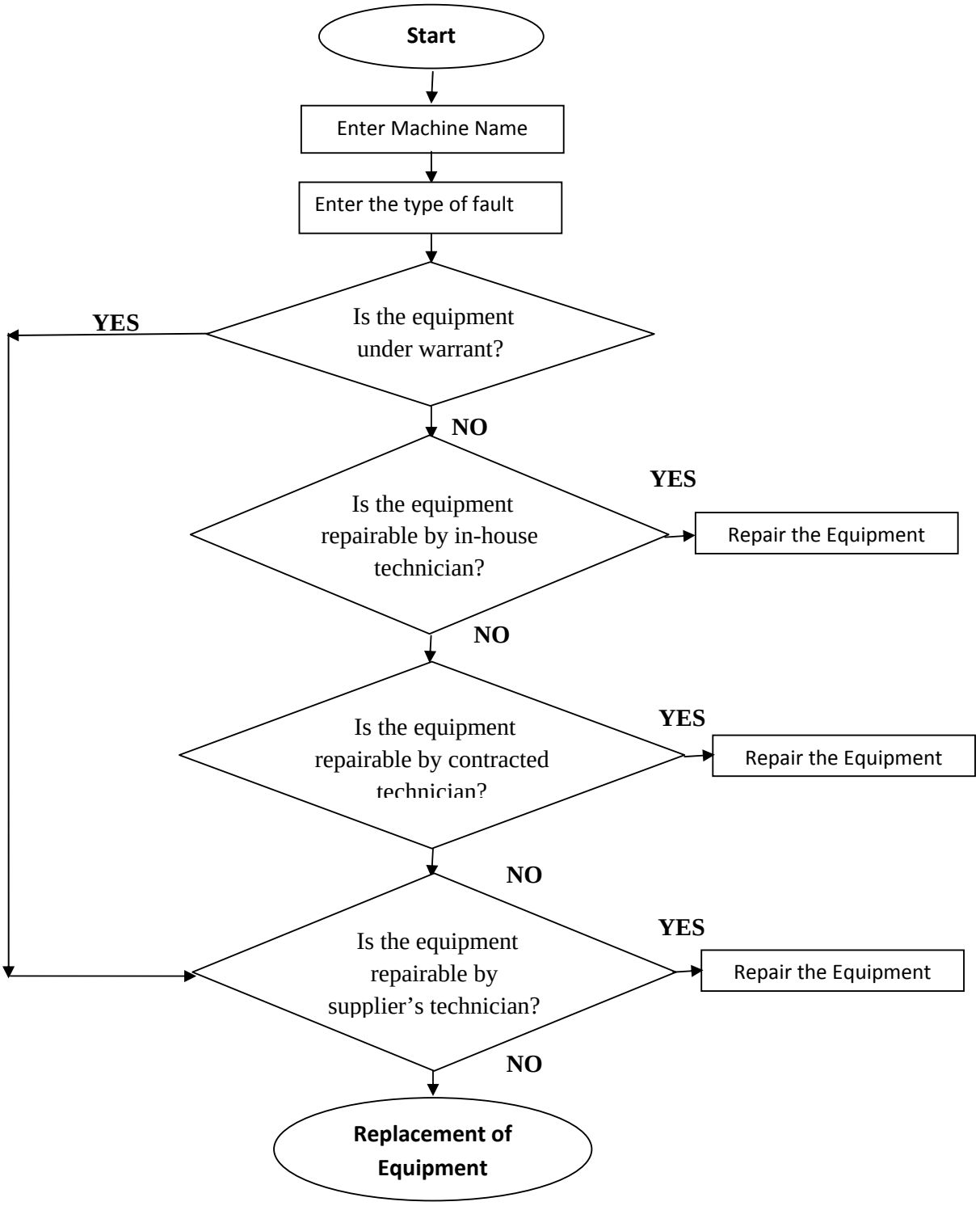


Figure 3.1: Maintenance flowchart program

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Technology Assessments and Selection

4.1.1 Introduction

This parameter assesses the role of facility managers in each organization to survey and select equipment before they are purchased. The evaluation was made through the performance of the medical equipment on technology assessments and selection. A fifteen question questionnaire covered factors in ; *selection of equipment, medical equipment performance with reference to environment and Unique Device Identification (UDI)* was administered in selected public and private hospitals. The following sections give the results of the findings;

4.1.2 Technology Assessments and Selection in Private Hospitals

Figure 4.1 shows histogram on the performance weighting of technology assessments and selection for medical equipment in private hospitals. It is seen from the chart that most of the maintenance management in these hospitals are above 3 indicating there is good selection of the equipment before the purchase process is properly performed in all the three hospitals. Some of the factors considered effectively during selection includes safety, infection control and decontamination, effective performance, financial requirements, full life costs, compatibility with existing equipment, reliability etc. However some organizations in the private sector do not place em-

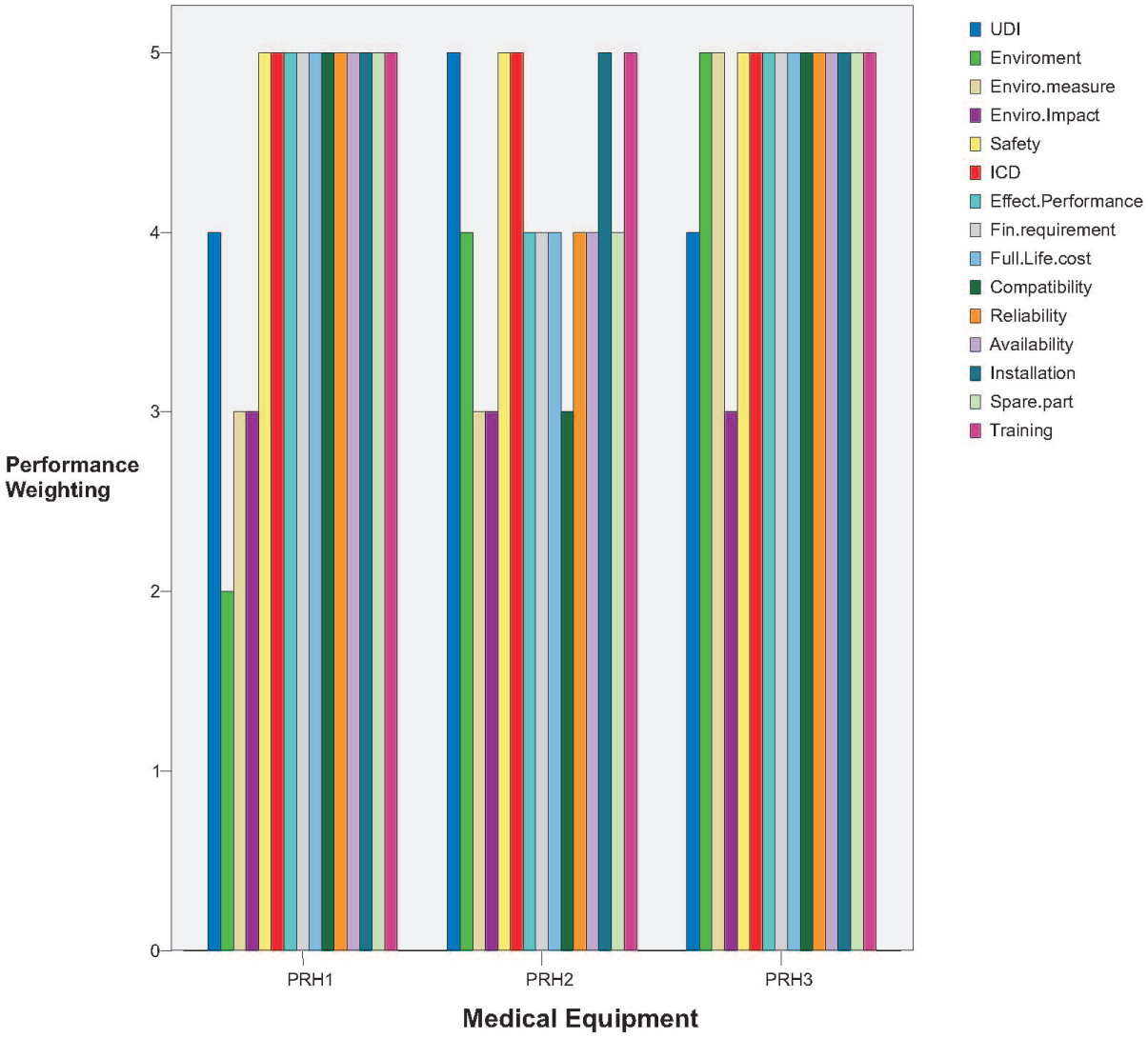


Figure 4.1: The weighting performance technology assessments and selection in private hospitals

phasis on the environmental effect to the equipment management.

4.1.3 Technology Assessments and Selection in Public Hospitals

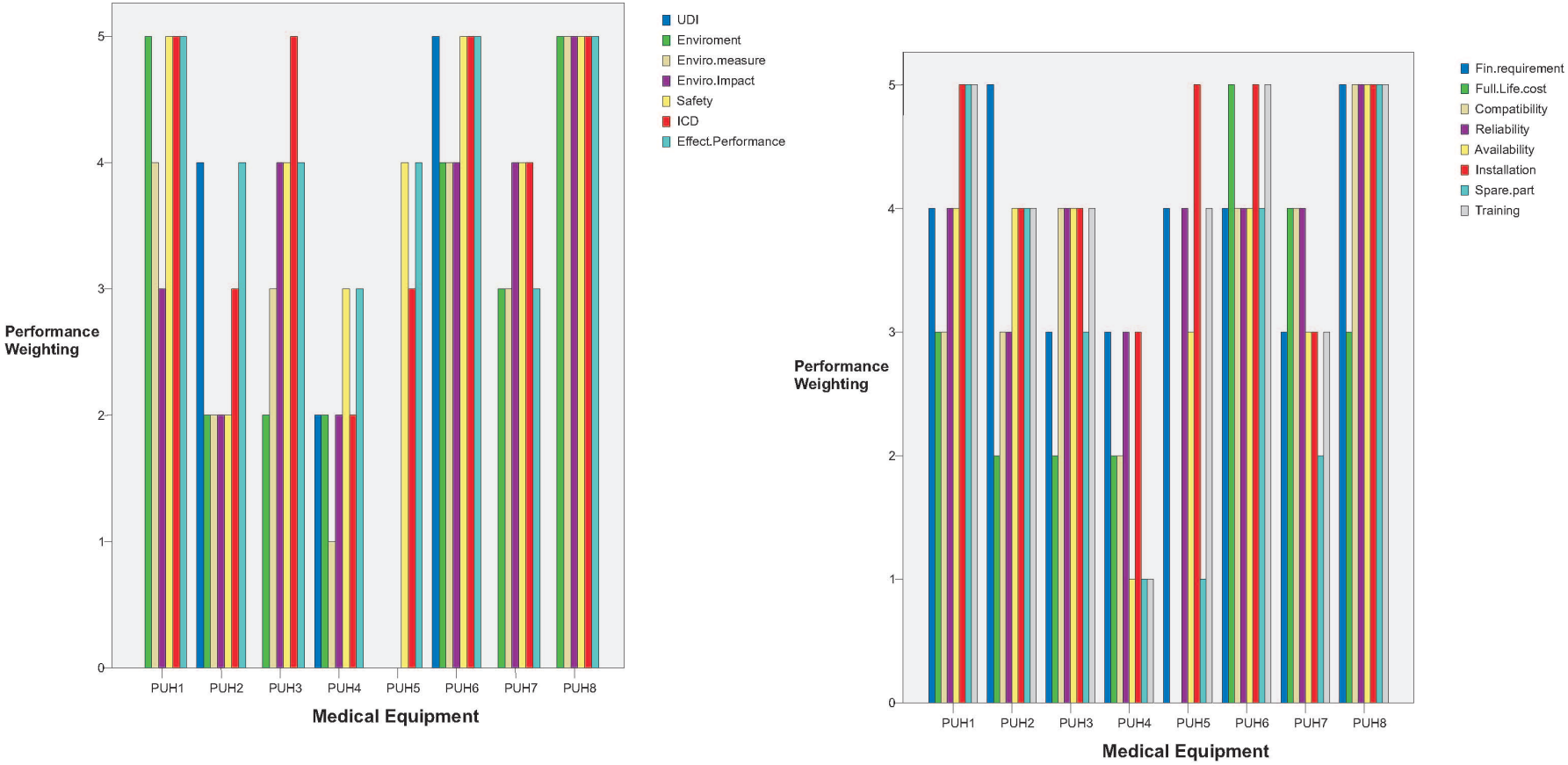
Figure 4.2 shows the histograms charts on performance weighting of technology assessment and selection for medical equipment in public hospitals. The PUH6 and PUH8 performs above 4 indicating that the selection of the laboratory equipment and other medical equipment before the equipment are purchased is very good. Most of the factors considered adequately on the selection includes safety, infection control and decontamination, effective performance, financial requirements, full life costs, compatibility with existing equipment, reliability etc. The maintenance organizations in the hospitals however do not consider compatibility and full life cost of the equipment. In the other public hospitals they operates below 2 indicating selections of equipment are poorly performed due to some inadequate consideration on the selection of equipment. These consideration include safety, infection control and decontamination, effective performance of the equipment, full life cost, reliability of the equipment, availability of spare parts and installation requirements. The environmental effects to the equipment are less considered. The availability of the unique device identification service chart is not adequately provided after the purchase of new equipment.

4.1.4 Technology Assessments and Selection in Consultant Firms

Figure 4.3(a) shows the performance weighting of technology assessment and selection for medical equipment in consultant/supplier firm. The CST1 and CST2 are not fully involved in most equipment selection before purchase. It can be seen from this figure that the maintenance managers in these institutions do not consider adequately some of the important factors on selection of the equipment. The CST3, CST4 and CST5 facility managers are more involved in the selection and they consider most of the factors which contribute to technology assessment and selection.

4.1.5 Technology Assessments and Selection in Contractor Firms

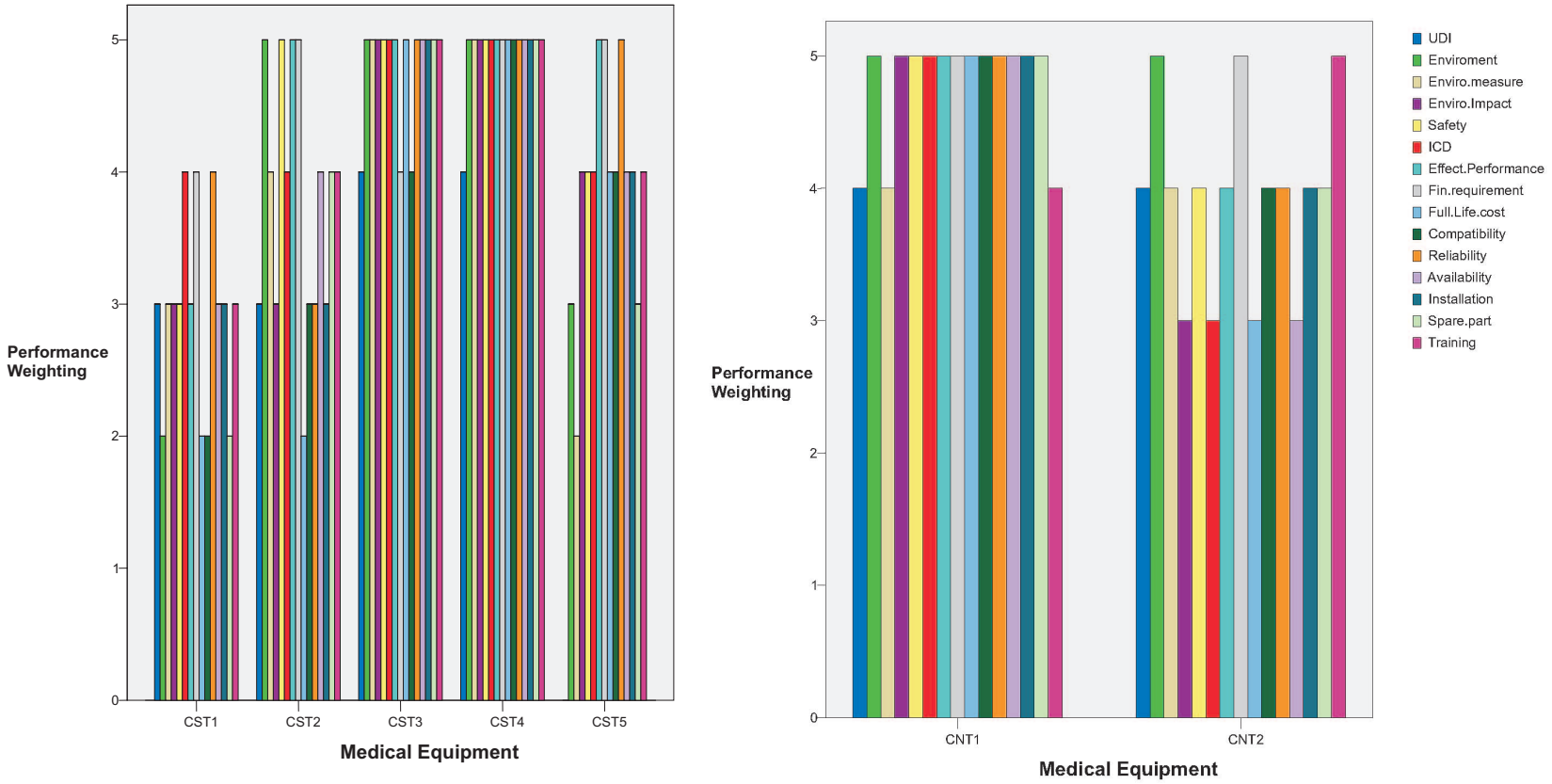
Figure 4.3(b) shows the performance weighting of technology assessment and selection for the medical equipment from contracted firms. It can be revealed from the figure that the availability of the spare part is considered on selection of equipment. The maintenance managers are consulted when selection is made on spare parts or equipment of the modern equipment. The two institutions perform better when considering factors contributing to technology assessment and selection of the devices and equipment.



(a) Public

(b) Public

Figure 4.2: The performance weighting of technology assessment and selection in public hospital



(a) Consultant

(b) Contractor

Figure 4.3: The performance weighting of technology assessment and selection

Figures 4.1 - 4.3 shows the performance weighting of technological assessment and selection for medical equipment from public, private, consultant and contracted institutions. The combined percentage mean ratings for the respective maintenance organizations are 67, 89, 80 and 87 per cent respectively. Analysis of combined mean score revealed that performance of the private maintenance organisation, with a rating of 89 per cent, is operating within the Excellent stage. Public hospitals are not effective in terms of proper selection as this has contributed to the failure of the equipment management in their institutions. Despite having a good performance in selection of the equipment most of their practices lead to earlier failure rate of the equipment either through manufacturing faults, design faults and misuse of the equipment as they selected faulty equipment. The following factors are not wholly considered; safety, infection control and decontamination, effective performance of the equipment, full life cost, reliability of the equipment, availability of spare parts and installation requirements. The main weakness in all organizations in technological assessment and selection of the equipment included:

1. The environmental effects to the equipment are less considered
2. The availability of the unique device identification service chart are not adequately provided when the new equipment are purchased.

All organizations should consider medical equipment performance with reference to the change of environment before purchasing the equipment; they should advice the supplier to undertake environmental measures and ways to reduce the environmental impact on medical equipment. The equipment should be bought from reliable companies. Technical and user manuals should be provided and the equipment should have standard parts before the equipment are purchased. The availability of spare parts will reduce the down time of the medical equipment. Increasing numbers of

medical devices and complexity with increased attention to field problems has led to an increase number of recalls. The absence of Unique Device Identification (UDI) means hospitals often must use manual and imprecise systems to find and properly identify recalled devices. Implementing UDI in combination with device tracking would potentially increase patient safety and decrease the work load and cost to address recalls. Finding patient care devices when and where clinicians and other personnel need them is crucial to patient care. The maintenance managers from most of the hospital fail to assess the new technology when selecting new equipment thus compromising the patient safety. The finding shows that the maintenance managers from the public hospitals needs to improve on technology assessment of the equipment and their selection before the institutions buys them.

4.2 Procurement and Logistics

4.2.1 Introduction

The evaluation of facility managers in hospitals on how to manage medical equipment was based on assessment of medical equipment performance through procurement and logistics . Seventeen question in a questionnaire covered factors in; *purchase order, up to date equipment inventory, equipment procurement program, construction qualities, mechanical quality, ease of maintenance compatibility with existing systems, requirement of installation, environmental and safety issues of the equipment.*

4.2.2 Procurement and Logistics in Private Hospitals

Figure 4.4 shows the performance weighting of procurement and logistics for medical equipment in private hospitals. It can be revealed that the performance of the maintenance managers from the private hospitals on the issue of procurement and logistics was above 3, indicating that procurement of medical equipment by the private hospitals were good. However the organizations have no appropriate systems for the procurement process. The organizations maintain an up to date inventory of all equipment within the department and standard operating procedures in place. The organizations have plans also to invest in medical equipment and other facilities.

4.2.3 Procurement and Logistics in Public Hospitals

Figure 4.5 shows the performance weighting of procurement and logistics for the medical equipment in public hospitals. It is seen from the chart that procurement and logistics in most of public hospitals are below 2. Factors contributing to the procurement and logistics for medical equipment are poorly considered in the public hospitals. The organizations to some extent maintains an up to date inventory of all equipment within the department and also standard operating procedures for all the equipment. Servicing of the equipment are not done to the manufacturer's recommendation.

The PUH1, PUH8 and PUH6 are the institutions which are operating above 3 on factors regarding to procurement and logistics as seen from figure 4.5. The PUH6 and PUH8 ensures the purchase order is provided to the service technician before leaving the facility and also the technicians are involved in making pre-purchase evaluations of equipment at the written request to the vendor compared to PUH 1. The organization had plans to invest in medical equipment and other facilities,

however the institution needed to improve the program for procurement process. They did not fully maintain an up to date inventory for all equipment within the department and also standard operating procedures. The PUH6 had appropriate program for procurement process. The purchase order has to be provided to the service technician before leaving the facility. The biomedical technicians were involved in making pre-purchase evaluations of equipment at the written request to the vendor.

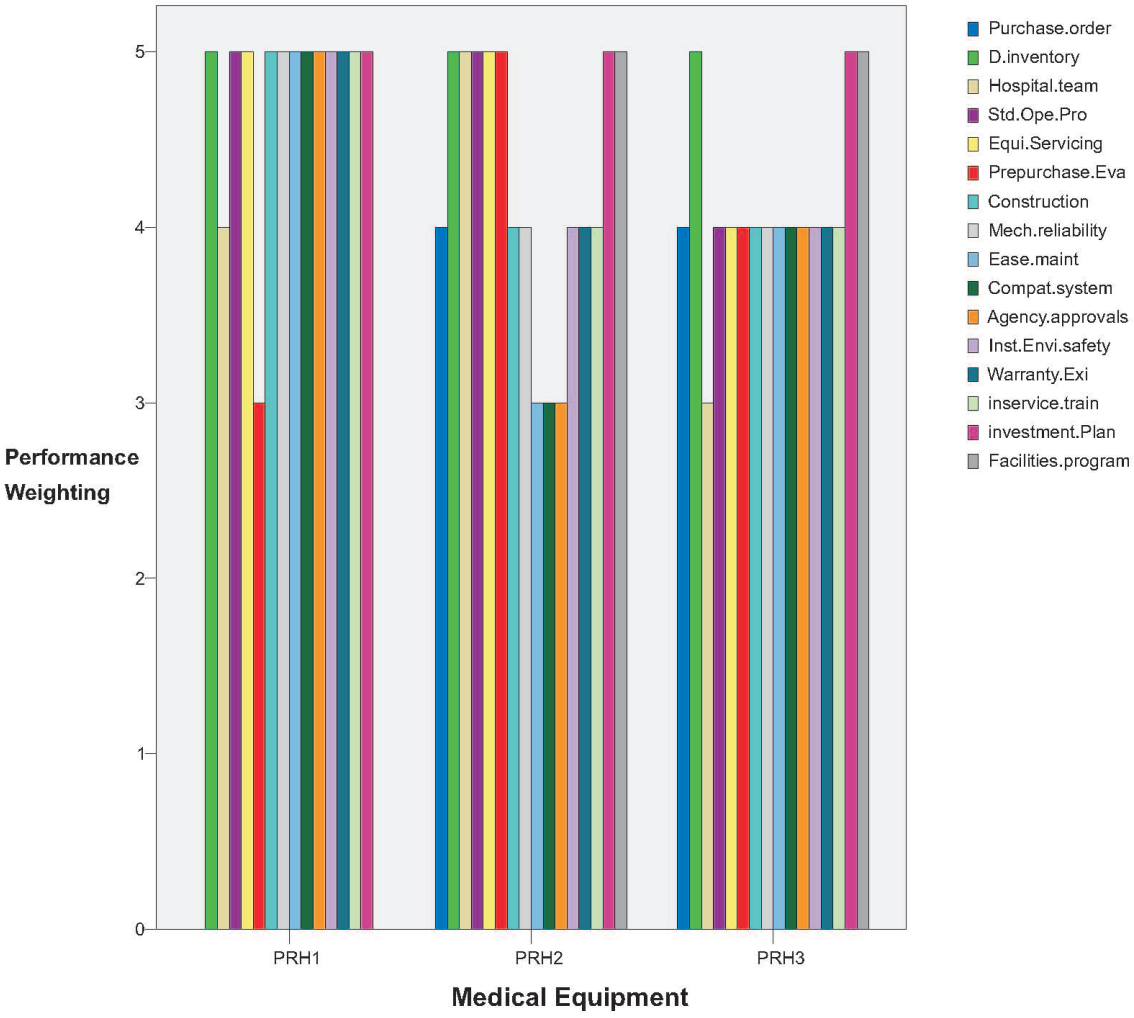
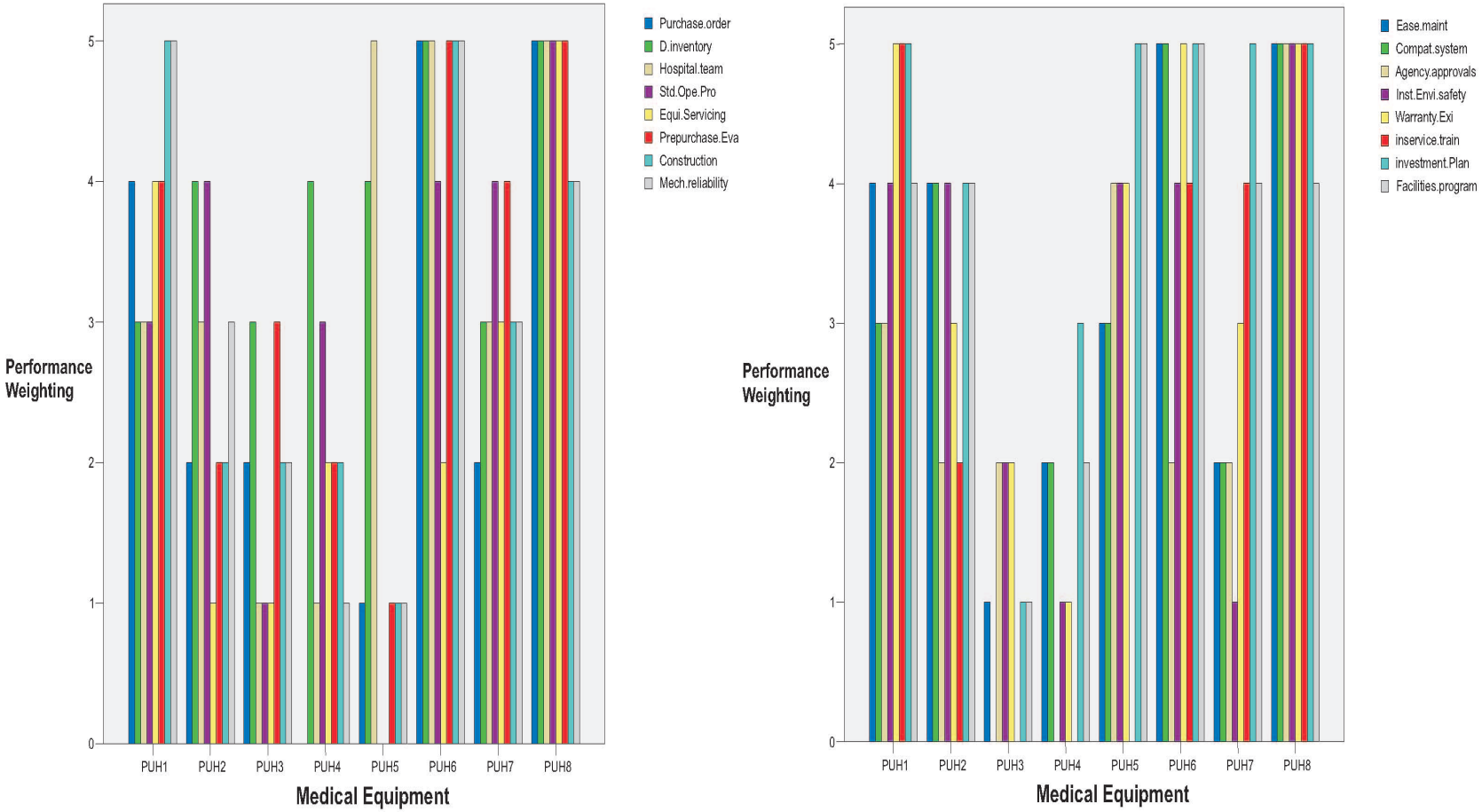


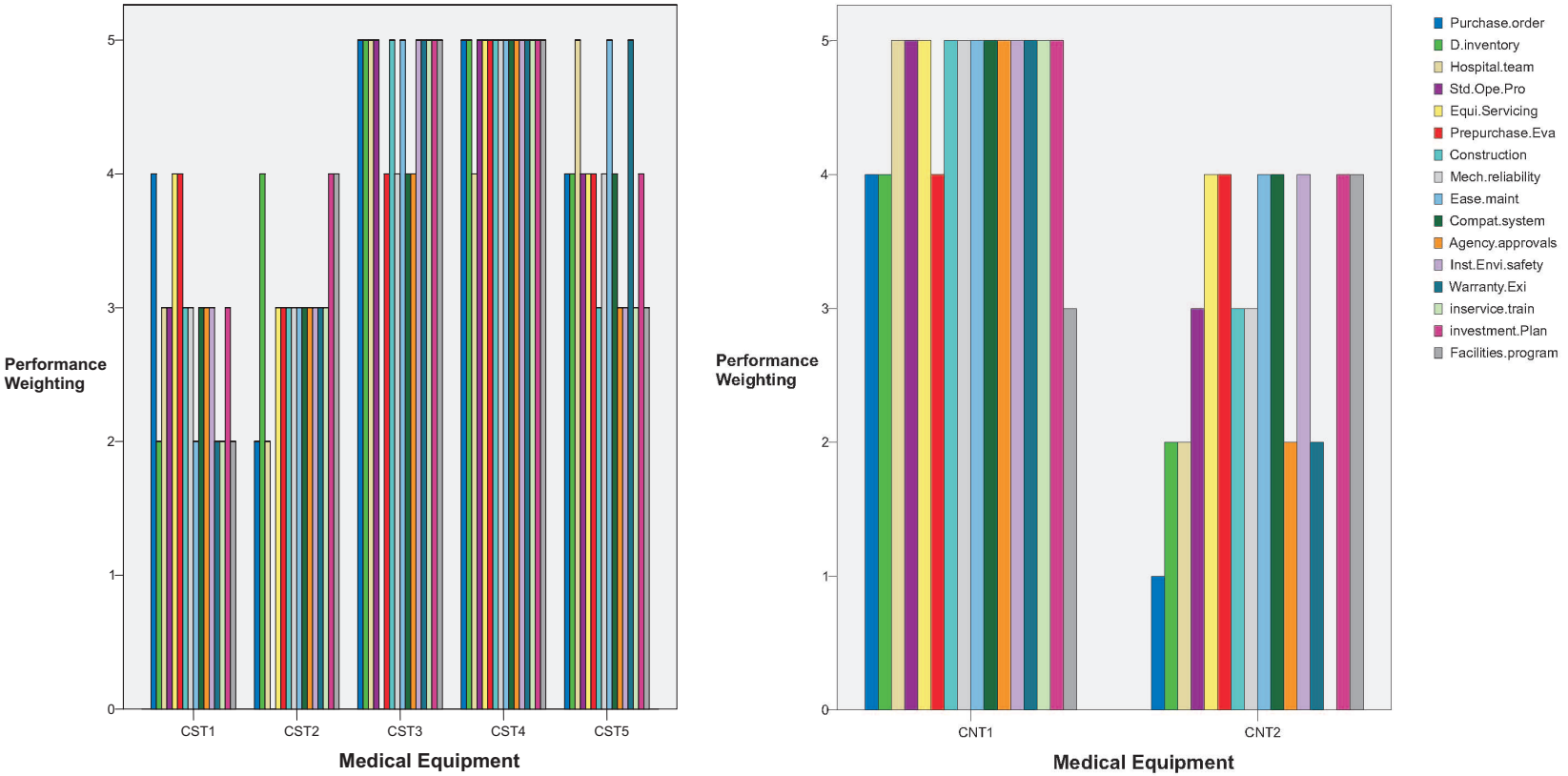
Figure 4.4: The performance weighting of procurement and logistics in private hospitals



(a) Public

(b) Public

Figure 4.5: The performance weighting of procurement and logistics in public hospitals



(a) Consultant

(b) Contractor

Figure 4.6: The performance weighting of procurement and logistics.

The evaluation of the equipment to some extent included the equipment compatibility with existing systems, requirement of installation, environmental and safety issues. The organization maintained an up to date inventory of all equipment within the department and standard operating procedures in place, however servicing of the equipment are not done to the manufacturer's recommendation.

4.2.4 Procurement and Logistics in Consultant Firms

Figure 4.6(a) shows the performance weighting of procurement and logistics for medical equipment in consultant firms. The evaluation of the equipment included; support requirement after warranty expiration, compatibility with existing systems among others. The CST1 and CST2 performs at level 2 which is a poor performance. The three other consultant firms operates above 3, indicating good management in procurement of medical equipment. The maintenance facility managers from CST1 do not maintain an up to date inventory of all equipment within their department. The evaluations of their equipment are not confined to the construction quality, support requirement after warranty expiration or development of equipment in service training. Although the organizations had plans to invest in medical equipment and other facilities they do not have proper infrastructure and program for procurement. The procurement and logistics excises are not well delivered in CST2. They do not participate as a team in equipment selection arrangement. The institution does not provide a purchase order to the service technicians before leaving the facility. The CST3, CST4 and CST5 performed better in equipment procurement. The purchase order is provided to the service technician before leaving the facility. The institution's technicians were involved in making pre-purchase evaluations of equipment at the written request to the vendor. The organizations maintained an up to date

inventory for all equipment within the department and standard operating procedures in place, however technicians from CST3 did not perform maintenance on the equipment as per the manufacturer's recommendation.

4.2.5 Procurement and Logistics in Contractor Firms

Figure 4.6(b) shows the performance weighting of procurement and logistics for medical equipment in contracted firms. It seen from the chart that CNT1 performs their procurement of medical equipment better than CNT2. The CNT1 operates above 3, indicating good performance on procurement and logistics. The purchase order is provided to the service technician before leaving the facility with institution's technicians being involved to make pre-purchase evaluations of equipment at the written request to the vendors. The technicians performs team work in equipment selection ensuring standard operating manuals are in place for the equipment and servicing are performed to the manufacturing recommendations. However the program for the procurement needed more improvement. The technicians from CNT2 are not included mostly in procurements activities. The technicians do not participate in equipment selections or maintains an up to date inventory of the equipment and spares. The purchase order is not provided to the technicians before the purchase is made. Despite poor evaluation of the equipment, proper servicing of the equipment is performed to the manufacturer's recommendation.

Figures 4.4 - 4.6(b) shows the performance weighting of procurement and logistics for medical equipment from public, private, consultant and contracted institutions. The analysis of combined percentage mean ratings for the respective maintenance organizations are 62, 83, 76 and 74 per cent respectively. Except for the public maintenance organization, the other facility managers have excellent procedures to

acquire the best equipment in their procurement processes. All the organizations demonstrated several weaknesses as highlighted by the findings below;

The organizations are less involved in the following procurement procedures:

- Purchase of the equipment.
- Equipment selection
- The purchase order requirements
- Making pre-purchase evaluations of the equipment through written request to the vendor.

To some extent the organizations do not maintain an up to date inventory of all equipment within the department and also standard operating procedures for all the equipment.

4.2.6 Maintenance Managers in Private Hospital

The purchase order is not provided to the service technician or they are not fully consulted before existing the facility.

4.2.7 Maintenance Managers in Consultant Firms

Some consultants do not participate as a team in equipment selection arrangement. The institution does not provide a purchase order to the service technicians before leaving the facility.

4.2.8 Maintenance Managers in Contractor Firms

Some of the contractors do not participate in equipment selections, or an up to date inventory of the equipment and spares. The purchase order is also not provided to the technicians before the purchase is made.

The institutions managements or hospital boards do not involve the facility maintenance managers in equipment selections or evaluations. This has contributed to acquisition of incorrect equipment by the hospitals or equipment which have difficulties in acquiring spares parts for them. The warrant of the equipment do not cover most of the crucial needs which leads to earlier failure of the equipment. Lack of co-operation between hospital management and facility maintenance managers leads to equipment management being compromised. The facility maintenance manager from public hospital should develop an up to date inventory system. This will aid the maintenance department on identification of the type and amount of the equipment in the system also it will help identify the new technology in the market.

4.3 Installation and Commissioning

4.3.1 Introduction

The evaluation of facility managers in each organization was analyzed by assessing the performance of the medical equipment on installation and commissioning. A ten question questionnaire covered factors in; *relevant standards of the equipment, damaged equipment, equipment inventory, routine maintenance program and equipment manuals.*

4.3.2 Installation and Commissioning in Private Hospitals

Figure 4.7(a) shows the performance weighting of installation and commissioning for medical equipment in Private hospitals. The technicians from the private hospitals perform most of the requirement in the installation and commissioning of the medical equipment in their respective institutions. The equipment are always safe to use and complies with all relevant standards, however technical manuals and in service training from the manufacturers may not be provided.

4.3.3 Installation and Commissioning in Public Hospitals

Figure 4.7(b) shows the performance weighting of installation and commissioning for medical equipment in public hospitals. The technician from PUH1, PUH6 and PUH8 performs better than other public hospitals in the installation and commissioning of the medical equipment. It is seen from the chart that in the three hospitals installation and commissioning of medical equipment are performed above level 3. The equipment are considerably safe to use on arrival and complies with most of relevant standards. They match the order and arrives complete with accessories. Most of the equipment are registered on the division inventory and also given asset identification before being placed on a routine maintenance programme. The technical manual is provided by the suppliers and a copy of user manual is mostly provided. The new and overhauled equipment are commissioned before use and a detailed tag is attached on all equipment. In other public hospitals they operate below level 2. Proper installations and commissioning of new equipment is poorly performed by the departmental engineer. The new and overhauled equipment are commissioned before use however a statement does not necessary appear on all equipment quotes to assure compliance with applicable standards and codes. The

engineer somewhat verifies whether the equipment are safe to use on arrival with no damages and matches the order. Some of the equipment are not registered on the division inventory and also not always given asset identification before being placed on a routine maintenance programme. The technical manual are not guaranteed given by the suppliers however one copy of user manual is mostly provided.

4.3.4 Installation and Commissioning in Consultant Firms

Figure 4.8(a) shows the performance weighting of installation and commissioning for medical equipment in consultant firms. It seen from the chart that the two firms are below 2. The installation and commissioning practice are poorly executed by the CST1 and CST2 technicians compared to the service provided by maintenance managers of the other three consultant firms. Technical manuals for medical equipment are not well provided. In CST1 the equipment do not meet specified performance criteria on arrival. Equipment are inappropriately registered on the division inventory and also not always given asset identification before being placed on a routine maintenance programme.

4.3.5 Installation and Commissioning in Contractor Firms

Figure 4.8(b) shows the performance of installation and commissioning for medical equipment in contracted firms. Technical manuals are not well provided in CNT2 firm. Figures 4.7(a) - 4.8(b) shows the performance weighting of installation and commissioning for medical equipment from public, private, consultant and contracted institutions. The combined percentage mean ratings for the respective maintenance organizations are 74, 93, 83 and 86 per cent respectively. Higher ef-

fectiveness rating means higher performance, corresponding to the respective stage. The analysis of combined mean rating revealed that maintenance managers from private hospital had an excellent practices in installation and commissioning of medical equipment. The public hospitals maintenance managers however had lower standards compared to the rest of the organizations. Nevertheless, there existed some areas of weakness revealed from the evaluation on all the organization as highlighted by the finding below;

4.3.6 Maintenance Managers in Public hospital

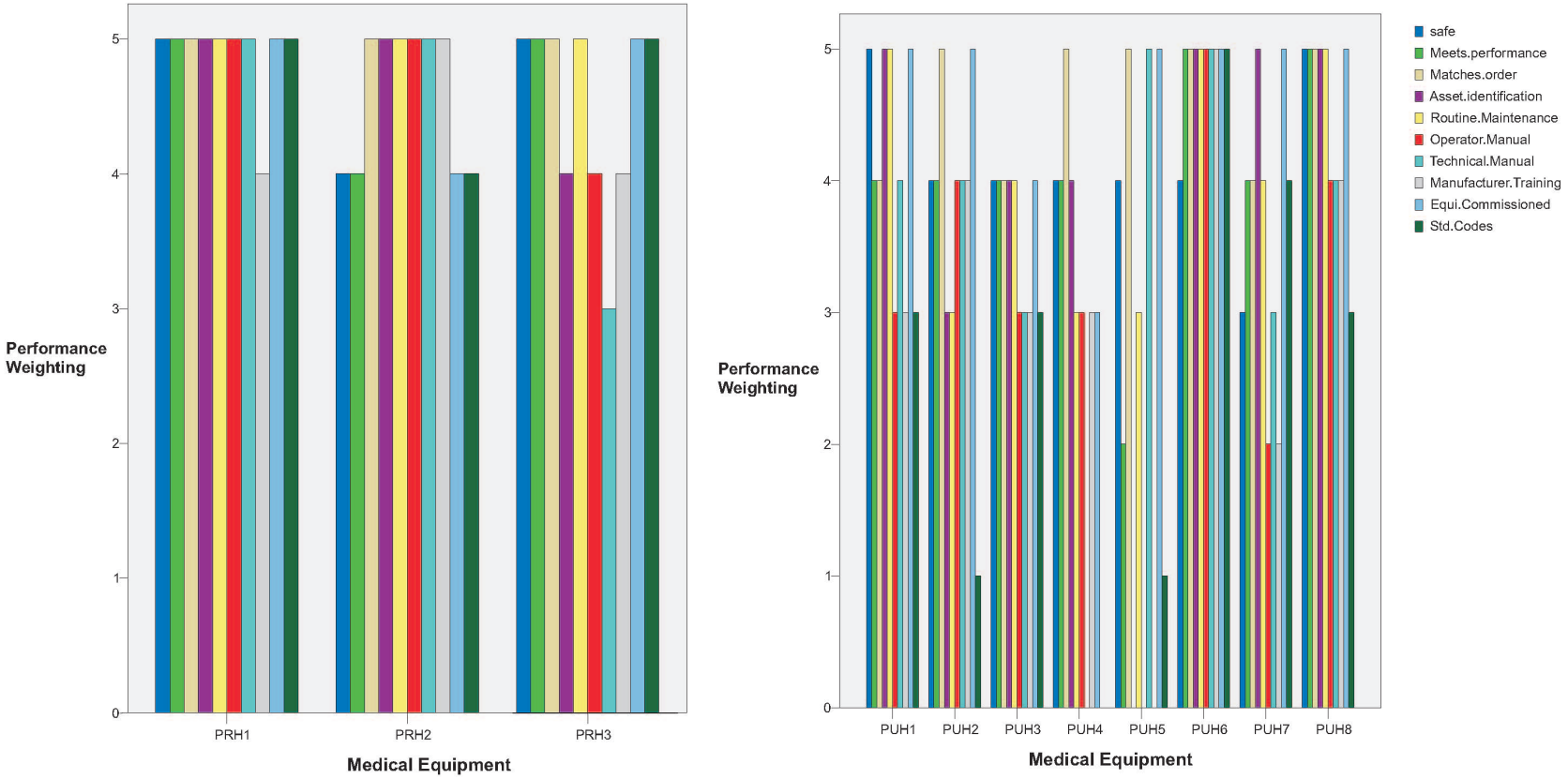
Identification statement of the equipment does not appear on all equipment quotes to assure compliance with applicable standards and codes after an installation procedure have been performed. In-service training and technical manuals are not always provided for.

4.3.7 Maintenance Managers in Consultant Firms

The operator's manuals, technical and in-serving training by some of the suppliers has difficulties to acquire.

4.3.8 Maintenance Managers in Contractor Firms

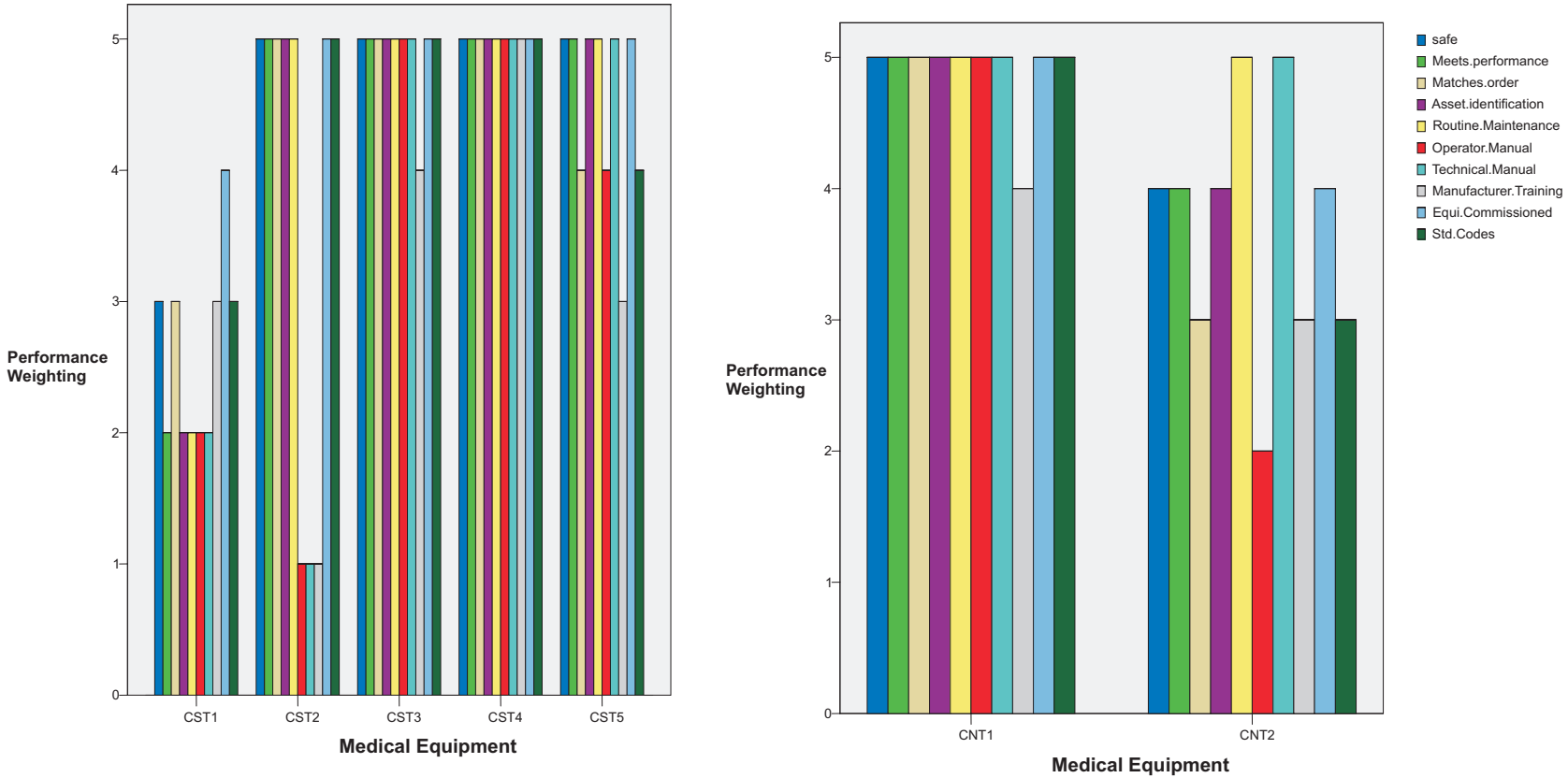
The availability of the operators manuals are not guaranteed



(a) Private Hospital

(b) Public Hospital

Figure 4.7: The performance weighting of Installation and Commissioning.



(a) Consultant

(b) Contractor

Figure 4.8: The performance weighting of Installation and Commissioning.

All equipment must be formally accepted into service by the facility maintenance managers who ensures that the equipment are safe to use and complies with all required standards. The equipment should meet the specified performance criteria and it should not be damaged. It should also match with the order and arrive complete with specified accessories. The equipment must be placed on a routine maintenance programme and the maintenance personnel must be trained and conversant with its use and servicing arrangements. Most of public hospitals maintenance team do not implement these basic requirements properly. They do not check whether the equipment meet specified performance criteria, whether they are damaged, matches the order and arrives complete with specified accessories. The availability of the technical and operational manual is not guaranteed. Since the suppliers may not offer training to the public hospital maintenance team as result they become incompetent not conversant with the equipment model and also servicing arrangements.

4.4 Training and Skill Development

4.4.1 Introduction

This parameter assesses and identifies whether facility managers are oriented and trained regarding maintenance management of medical equipment. The training and skill development attained by the facility managers was evaluated through the performance of the medical equipment in the hospital. A questionnaire of seventeen question had covered factors in; *pre-programmed or user configurable profile medical devices, computerized medical maintenance system (CMMS), training policy and programme, equipment manuals and training guides and further training of facility managers on medical equipment.*

4.4.2 Training and Skill Development in Private Hospitals

Figure 4.9 shows the performance weighting of training and skill development for medical equipment in private hospitals. It is seen from the chart that PRH1 and PRH3 are below 2. The maintenance department from PRH1 and PRH3 have no computerized medical maintenance system which could assist on maintenance of equipment. In PRH1 in-service training is not provided on medical equipment which are rented or loaned, on equipment involved in frequent breakdown and on all new employee. However, in PRH3 in-service training is not perfectly provided to the new employees or on all equipment prone to frequent break down and also to the new equipment after purchase. The training may be conducted by supplier's agents or technicians but not from the nurses. The training of maintenance manager from PRH2 on medical equipment is ranked above 3 in figure 4.9. The training and skill development in these private hospital may be rated as good. The in-service training is adequately provided to the new employees or on all equipment involved in frequent break down and also to the new equipment after purchase.

4.4.3 Training and Skill Development in Public Hospitals

Figure 4.10 shows the performance weighting of training and skill development for medical equipment in public hospitals. The public hospitals has no computerized medical maintenance system which could assist in medical equipment maintenance however, some of their equipment have in build program to assist the technician to diagnose the fault and provide the remedy. The training of maintenance managers from PUH1,PUH6 and PUH8 on medical equipment may be rated as very good. Most of the standard parameters in these three hospitals are above 3, compared to the other public hospitals. They are well trained and most of them proceed for

higher learning especially on medical equipment training.

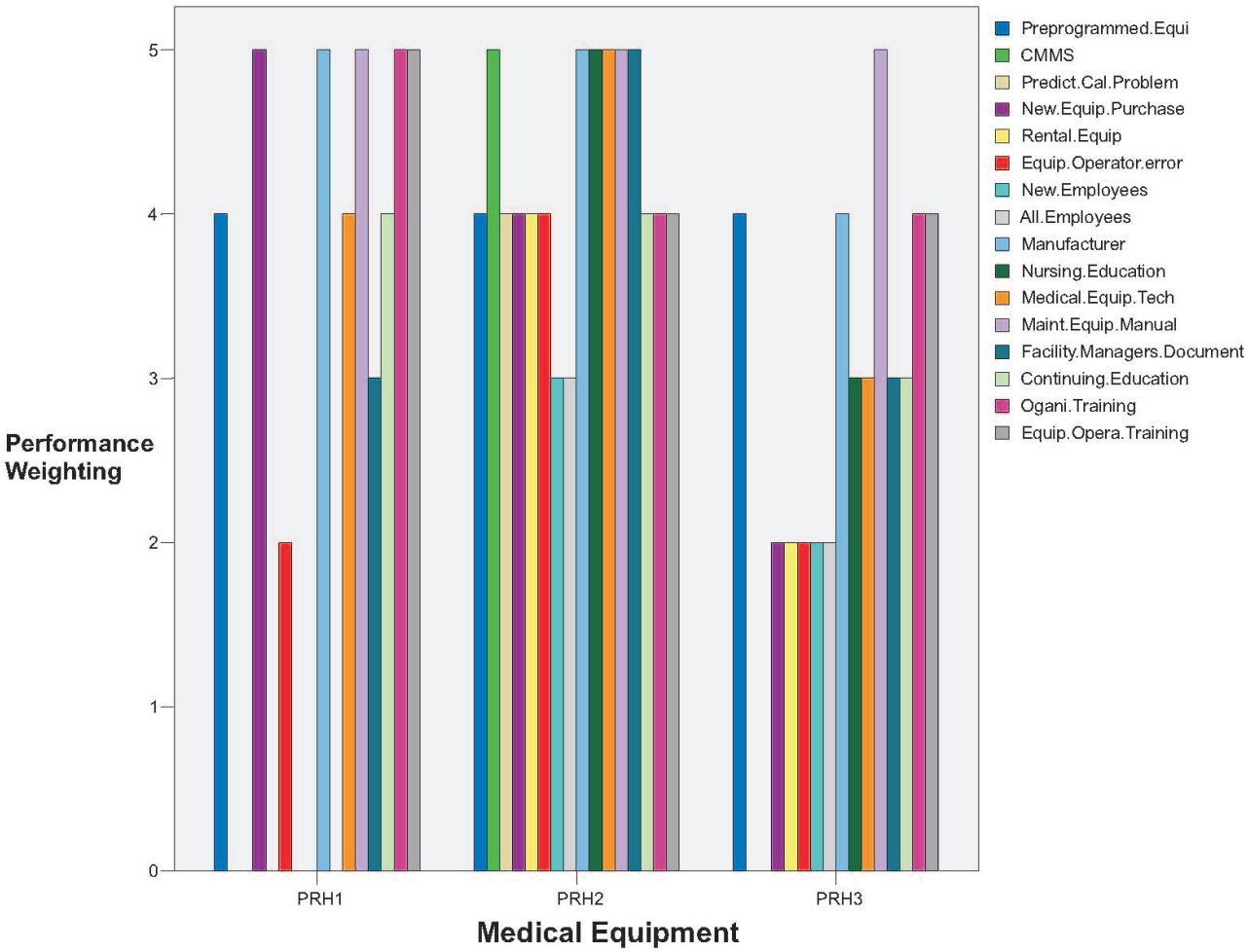
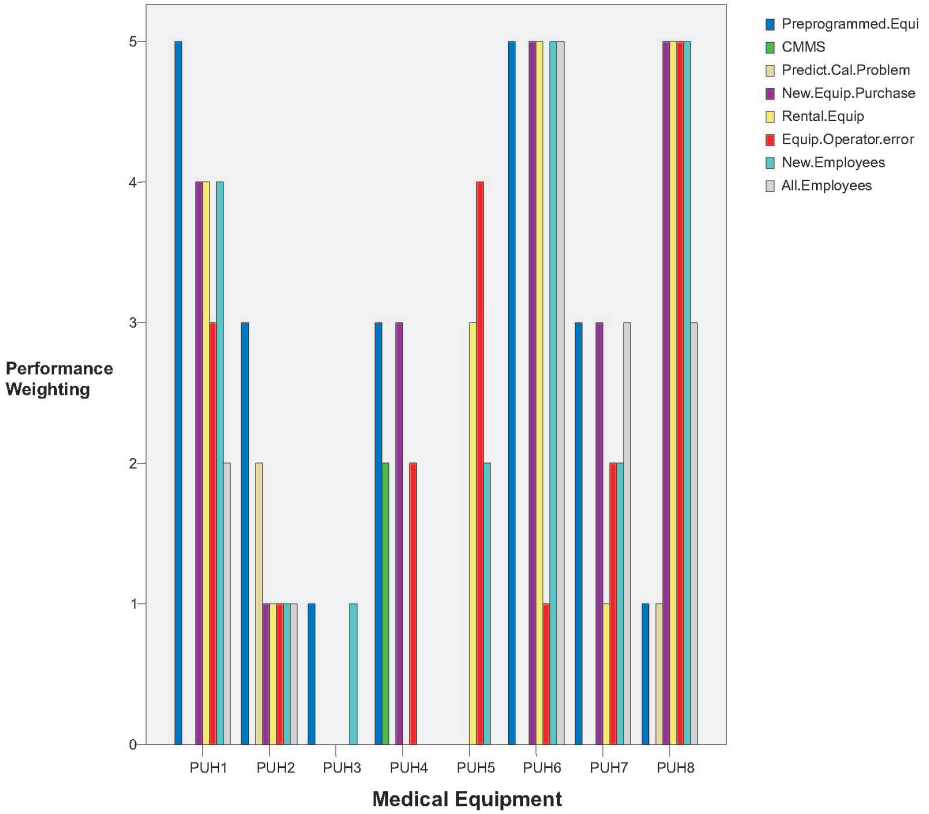
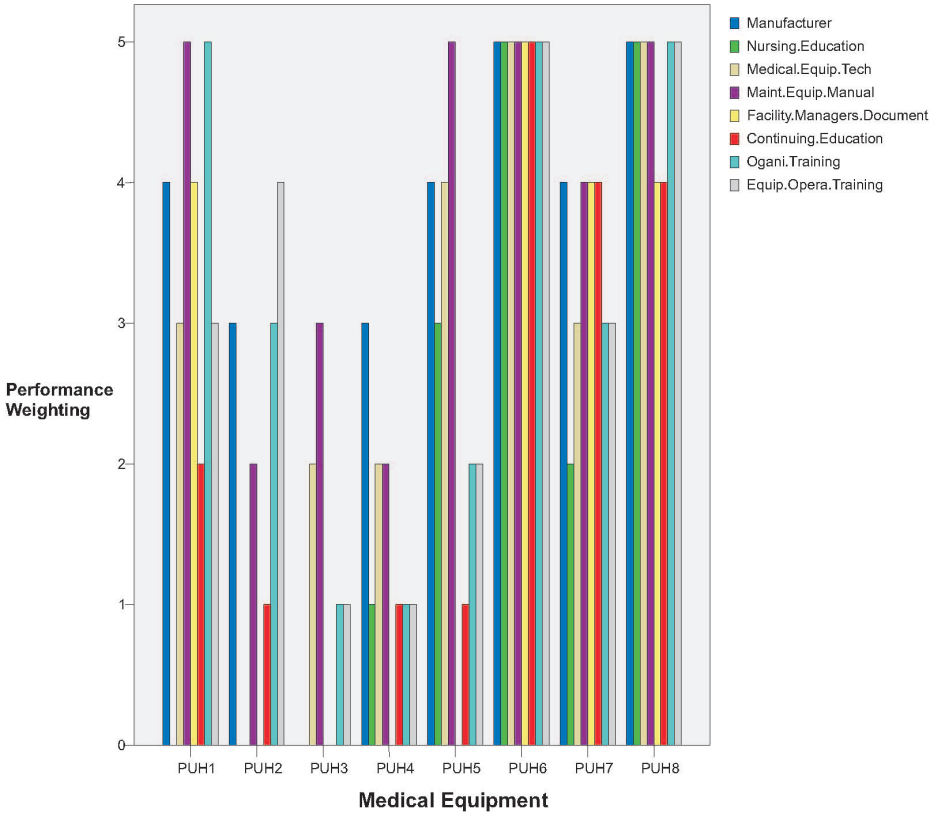


Figure 4.9: The performance weighting of training and skill development in private hospitals

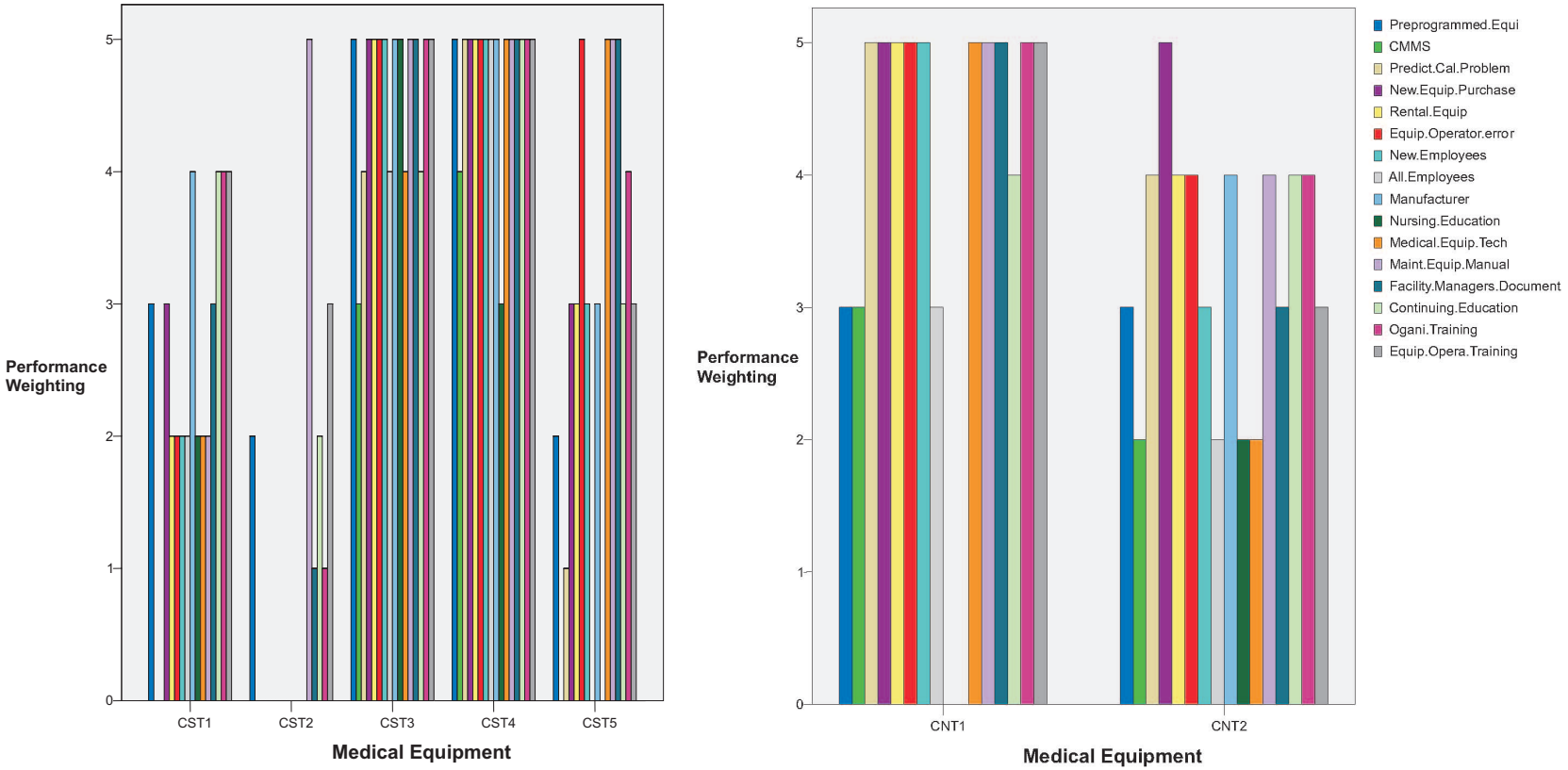


(a) Public



(b) Public

Figure 4.10: The performance weighting of training and skill development in public hospitals



(a) Consultant (b) Contractor

Figure 4.11: The performance weighting of training and skill development.

The in-service training is adequately provided to the new employees or on all equipment which are rented or loaned and also to the new equipment after purchase. However, most of maintenance managers are not trained on all equipment prone to frequent break down. The training may be conducted mostly by supplier's agents and technicians. Equipment manuals and training guides are available for each piece of equipment in most of the hospitals.

4.4.4 Training and Skill Development in Consultant Firms

Figure 4.11(a) shows the performance weighting of training and skill development for medical equipment in consultant firms. It can be seen from the chart that CST1,CST2 and CST5 are below 2. The consultant firms have no computerized medical maintenance system which could assist in medical equipment maintenance. Modern equipment being supplied to their clients have in build program to assist the technician to diagnose the fault and provide the remedy. The technicians can handle minor faults in pre-programmed or user configurable profile medical devices. The in-service training programs are not provided to the new employees, all equipment prone to frequent break down and all new equipment after the purchase. Most of the organizations do not fully maintain equipment manuals and training guides also they do not document orientation and annual review of employee proficiency in use and safety of each type of device. The technicians are not well trained and some of them do not proceed for higher learning and training on medical equipment. The CST3 and CST4 companies are however well trained compared to the other three consultant firms. Most of their stardard parameters in training and skill development are above 3.

4.4.5 Training and Skill Development in Contractor Firms

Figure 4.11(b) shows the performance weighting of training and skill developments for medical equipment in contracted firms. The contracting firms are fairly trained to handle challenges emanating from the equipment. The organizations are capable of handling pre-programmed medical devices based on user context. The consultant firms have no computerized medical maintenance system which could assist in medical equipment maintenance. Most of the modern equipment have in build program which helps in diagnosing and repair of the equipment. In-service training is provided to the maintenance managers in the contracted firms.

Figures 4.9 to 4.11(b) shows the performance weighting of training and skill development for medical equipment from public, private, consultant and contracted institutions. The combined percentage mean ratings for the respective maintenance organizations are 47, 63, 62 and 72 per cent respectively. The analysis of combined mean rated the maintenance managers from public hospital to be at fair position on training programme of medical equipment. The training of equipment users and maintenance managers reduces the equipment downtime. To reduce the possibility of equipment malfunction following service or repair, all personnel involved in maintaining and servicing equipment must be trained fully to appropriate standards. From the data collected it demonstrated several weaknesses and failures by the facility maintenance managers.

4.4.6 Maintenance Managers in Public Hospital

The organizations have no computerized medical maintenance system which could either predict necessary preventive maintenance or analyze the data streams to predict calibration problems. The in-service training programs are not normally provided

to the new employees, on all equipment involved in frequent operator errors and all new equipment after the purchase. The training may be conducted by suppliers agents, however, the organization does not fully maintain equipment manuals and training guides. They do not document orientation and annual review of employee proficiency in use and safety of each type of device. The technicians are not well trained and most of them do not proceed for higher learning especially on medical equipment training.

4.4.7 Maintenance Managers in Private Hospital

The organizations have no computerized medical maintenance system which could either predict necessary preventive maintenance or analyze the data streams to predict calibration problems. Most of the organization do not provided in-service training to the new employees or on all equipment involved in frequent operator errors.

4.4.8 Maintenance Managers in Consultant Firms

The consultant have no computerized medical maintenance system which could either predict necessary preventive maintenance or analyze the data streams to predict calibration problems. Few of these organizations do not provided in-service training to the new employees or on all equipment involved in frequent operator errors.

4.4.9 Maintenance Managers in Contractor Firms

The contractor have no computerized medical maintenance system which could either predict necessary preventive maintenance or analyze the data streams to predict

calibration problems. Several of these organizations do not provide in-service training to the new employees or on all equipment involved in frequent operator errors. Equipment training is necessary in managing risk and establishing expectations for safe, quality and effective use. All health care employees who use medical equipment should be oriented to each type of device and be able to demonstrate proficiency in its use. In a given piece of equipment there are maintenance problems of different levels of complexity. The majorities of the problems are relatively simple and can be corrected by in-house maintenance manager trained in front-line maintenance. Training of public hospital maintenance team to a high level of skills has proven to be expensive although necessary. Furthermore, upon completion of their training staff are often lured away by companies paying higher salaries. However during the purchase of new equipment, suppliers can be requested to train in-house technicians in maintenance, often at no cost. Public hospitals maintenance organizations always take advantage of the opportunity during the purchase of new equipment by inclusion of this condition in the tender or purchase order. The concept does not work for their system as they lack credible training hence unable to repair most of the equipment. They are ranked to be 'fair' on their performance on training and skill development. The facility maintenance managers in public hospital should acquire proper training. This will enable the facility maintenance managers in public hospital repair the equipments effectively.

4.5 Operation and Safety

4.5.1 Introduction

This parameter is aimed at assessing overall performance of the services provided by the facility managers on operation and safety of medical equipment. The medical equipment were evaluated on effective operation and on safety integrity. A questionnaire had thirteen questions which covered factors in; *plans for the purchase and maintenance of equipment, inventories of equipment, maintenance are clearly documented, organization are equipped for the maintenance, safety procedures during maintenance operations, training programs on health and safety of equipment, testing procedures for operation and safety integrity of medical equipment.*

4.5.2 Operation and Safety in Public Hospitals

Figure 4.12(a) shows the performance weighting of operation and safety development for medical equipment in public hospitals. It seen from the chart that the PUH3, PUH4 and PUH5 are below 2. They are not perfectly equipped for the maintenance purposes. The hospital keep poor inventories of the equipment and its condition in its various units. The equipment listed in the medical equipment inventory have no written testing procedures for operation and safety integrity. The assignments for maintenance managers on equipment maintenance are not clearly documented. There is no clear plan for maintenance as well as follow up and analysis of faulty medical equipment. The organizations adhere to safety procedure during maintenance operation. They bring unsafe equipment operation to the attention of user and their supervisor by placing the stickers on the medical equipment to indicate

their conditions or using other means to alert potential users. The training programs for the technicians are not well related to the health and safety of the equipment. The procedures are not always developed from manufacturer's equipment service manuals and industry accepted testing criteria. The standard parameters in the operation and safety for PUH1,PUH2,PUH6,PUH7 and PUH8 are above 3. They are equipped for the maintenance purposes and fairly adheres to safety procedure during maintenance operation.

4.5.3 Operation and Safety in Private Hospitals

Figure 4.12(b) shows the performance weighting of operation and safety for medical equipment in private hospitals. It can be seen from the chart that the standard parameters in the operation and safety for private hospitals are above 3. The organizations are equipped for the maintenance purposes. The hospitals keeps current inventories of the equipment and its condition in its various units, each piece of the equipment listed in the medical equipment inventory has written testing procedures to test for operation and safety integrity. The assignment for maintenance managers on medical equipment are clearly documented. There is clear plan for maintenance as well as follow up and analysis of faulty medical equipment. The organizations adhere to safety procedure during maintenance operation. They bring unsafe equipment operation to the attention of user and their supervisor by placing the stickers on the medical equipment to indicate their conditions or using other means to alert potential users. The training programs for the technicians are related to the health and safety of the equipment. The procedures are not always developed from manufacturer's equipment service manuals and industry accepted testing criteria.

4.5.4 Operation and Safety in Consultant Firms

Figure 4.13(a) shows the performance weighting of operation and safety development for medical equipment in consultant firms. The consultant firms are equipped for the maintenance purposes on the high quality equipment supplied to their clients during the warrant period. The organizations to some extent participate to keep current inventories of the equipment and its condition in its various units. Maintenance managers ensure repair manuals and operation manuals are in place. The organizations adhere to safety procedures during maintenance operation. They bring unsafe equipment operation to the attention of user and their supervisors by identifying defective equipment and alerting potential users. The training programs for the technicians are less related to the health and safety of the equipment.

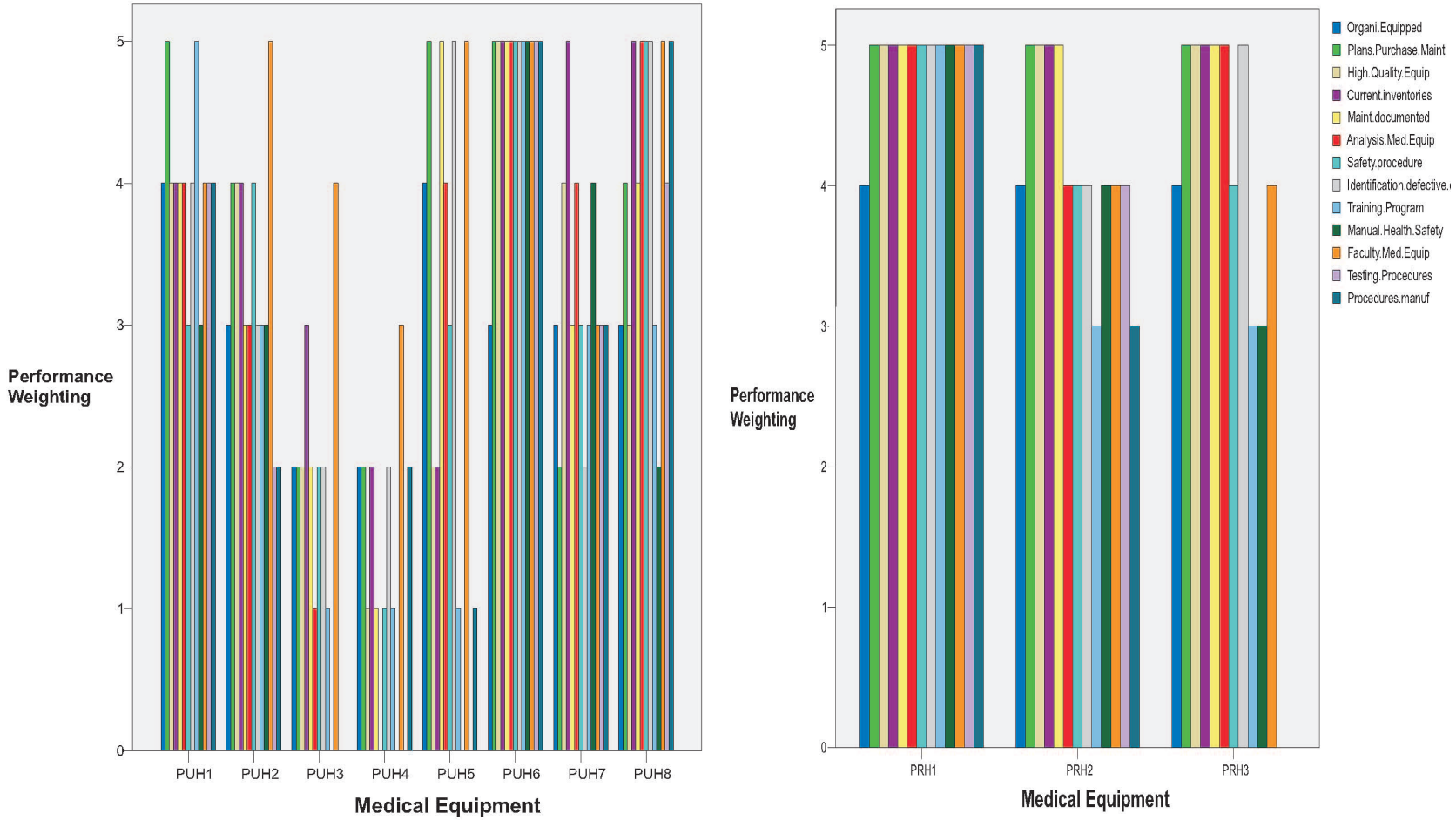
4.5.5 Operation and Safety in Contractor Firms

Figure 4.13(b) shows the performance weighting of operation and safety for medical equipment in contracted firms. The CNT1 is perfectly equipped for the operation and safety requirements while performing maintenance on the medical equipment. The maintenance managers participate to keep current inventories of the equipment and its condition in its various units. The equipment listed in the medical equipment inventory has written testing procedures to test for operation and safety integrity. The assigned duties for the maintenance managers are clearly documented. There is clear plan for maintenance as well as follow up and analysis of faulty medical equipment. The organization adheres to safety procedure during maintenance operation. They bring unsafe equipment operation to the attention of user and their supervisor by either placing the stickers on the medical equipment to indicate their conditions or through other relevant means. The training programs for the technicians are

related to the health and safety of the equipment which includes use of manuals on general health and equipment safety. The CNT2 is not adequately equipped for the maintenance purposes while emphasizing on safety of the high quality equipment in various hospitals. The organization do not participates adequately to keep current inventories of the equipment and its condition in its various units. Maintenance managers ensure repair manuals and operation manuals are in place. Safety procedures during maintenance operation are not well executed. There are no manuals on general health safety. They bring unsafe equipment operation to the attention of user and their supervisor by identifying defective equipment and alerting potential users. The training programs for the technicians are related to the health and safety of the equipment. Figures 4.12(a) - 4.13(b) shows the performance weighting of operation and safety for medical equipment from public, private, consultant and contracted institutions. The combined percentage mean ratings for the respective maintenance organizations are 63, 85, 83 and 81 per cent respectively. The analysis of combined mean indicated that private, consultant and contracted maintenance managers operates at an excellent stage. With the exception of facility managers from public hospital, other organizations were almost performing at the same position. Nevertheless, there existed some areas of weakness as highlighted by the findings below;

4.5.6 Maintenance Managers in Public Hospital

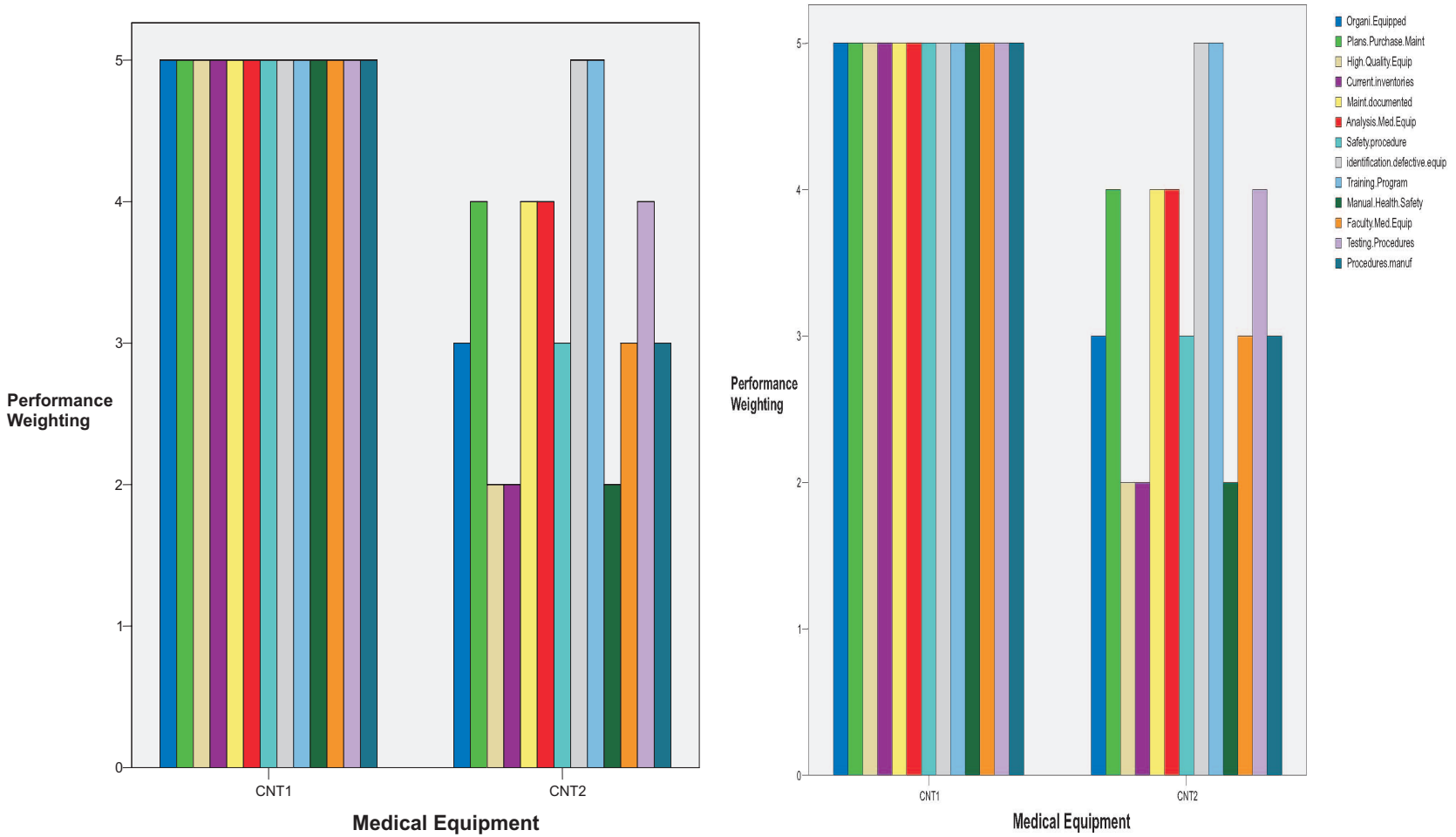
The organizations are not well equipped for the maintenance purposes despite most of the institutions having high quality equipment to be used for treatment purposes. They do not ensure each equipment listed in the medical equipment inventory has written testing procedures to test for operation and safety standards.



(a) Public Hospital

(b) Private Hospital

Figure 4.12: The performance weighting of operation and safety.



(a) Consultant

(b) Contractor

Figure 4.13: The performance weighting of operation and safety.

The organizations do not adequately adhere to safety procedures during maintenance operation. They do not necessarily bring unsafe equipment operation to the attention of the user and their supervisor by either placing the stickers on the medical equipment to indicate their conditions or through other means.

4.5.7 Maintenance Managers in Consultant Firms

Faulty medical equipment are not accessible by the maintenance team. Maintenance assignments on medical equipment are not clearly documented by the maintenance managers.

4.5.8 Maintenance Managers in Contractor Firms

The contractors are not adequately equipped for the maintenance purposes while emphasizing on safety of the high quality equipment in various hospitals. They do not participate in keeping current inventories of the equipment and its condition in its various units. Safety procedures during maintenance operation are not well executed as they have no manuals on general health safety.

The inspection of the equipment by the facility maintenance managers is performed to establish medical equipment achieving all applicable safety standards. The equipment should perform in accordance with manufacturer specification. Equipment passing the safety inspection should be tagged with an inspection sticker and entered into the inventory maintenance program. Equipment not passing safety tests are not placed into the service and should be tagged as *defective*. The facility maintenance managers do not have proper tools to determine the safety test and functional test. This has often contributed to faulty equipment being used by the patients. To

provide an electrically safe environment for all patients, visitors, and staff is by ensuring compliance with applicable codes and standards by the maintenance managers. Improvement on some of the failures by the public hospitals maintenance and contractors organizations could transform the respective organizations into better teams.

4.6 Maintenance and Repair

4.6.1 Introduction

The evaluation of facility managers in hospitals on how to manage medical equipment was based on assessment of medical equipment performance through its maintenance and repair. Medical equipment assessment was based on policies, plan and procedures of maintenance and repair done by facility managers. A questionnaire had seventy five questions which covered factors in; *corrective and preventive maintenance, spares management, infrastructure support, maintenance performance, equipment history and safety management.*

4.6.2 Maintenance and Repair in Private Hospitals

Figures 4.14 and 4.15 show the performance weighting of maintenance and repairs for medical equipment in private hospitals. The maintenance managers in PRH1 ensure corrective and routine preventive maintenance are performed in accordance with the manufacturer's specification or accepted industry standards. An updated inventory is placed on the records file following every bi-annual planned maintenance cycle. In the specialized trade for example refrigeration and welding process they are not

performed under the direct supervision of a Biomedical Engineers. The equipment are sent back into use after maintenance work has been carried out and the correct use of status card and certificates of serviceability are dully filled up. Adequate time is not allocated for the organization to perform preventive maintenance services on a scheduled basis. The institution emphasizes the responsibilities of equipment user to perform effective maintenance, e.g. cleaning. The facility manager does not guarantee that the operators are properly trained and competent in the use and care of medical equipment. This has lead to nurses becoming responsible for the most of the faults. Operators manual for all medical equipment are always available to the user. The maintenance shop despite being centralized does not have a secure enough storage space and it is not adequately furnished. There are no available resources necessary to maintain the hospital equipment. All repairs request are called in by appropriate authorized personnel, however, each request does not contain detailed equipment information and fault identification. The equipment repairs and testing action are recorded on a service report form and all completed service reports are assigned a result code.

The medical equipment are not effectively tested on both performance and electrical safety before a unit is placed into use from temporary storage and also before initial use. The equipment have no inspection tags which denote date of inspection and the initials of testing by the technician and also they have no ability to send periodic report to the organization when the device fails. All events are recorded and build a history of each item of equipment in conjunction with the hospital departments. The performance of scheduled preventive maintenance services on the medical equipment takes priority over corrective repairs. The services are completed as scheduled. However, deferment of maintenance may be required due to non-availability of manpower or other extenuating circumstance for instance lack of spare parts. The elements

for estimating the cost of repair; direct labour and spares are considered while performing the repairs. The complicated equipment are contracted and the calibrations for the equipment are performed as specified by the manufacturers. The organization has no other specialized teams apart from medical engineer e.g. mechanical engineers. The PRH2 and PRH3, however, ensure that the specialized trade in the maintenance department for example refrigeration, plumbing and welding process are performed under the direct supervision of a Biomedical Engineer. The organizations provides advice on servicing, repairs and modification of the equipment. The facility managers ensures that the operators are properly trained and competent in the use and care of medical equipment. All electrical safety inspection are made in compliance with standards set forth. They have adequate resources necessary to maintain the hospital medical equipment. The medical equipment are effectively tested on their performance and on electrical safety before a unit is placed into use from temporary storage and also before initial use. The equipment have inspection tags which denote date of inspection and the initials of testing by the technicians.

4.6.3 Maintenance and Repairs in Public Hospitals

Figure 4.16 to 4.19 shows the performance weighting of maintenance and repair for medical equipment in public hospitals. It is seen from the chart that PUH6 and PUH8 are above 2 compared to the other public hospitals. All corrective and routine preventive maintenance are performed in accordance with the manufacturer's specification or accepted industry standards in PUH6 as shown in Figure 4.16. Updated inventories are fully placed on the records file following every bi-annual planned maintenance cycle. The specialized trade for example refrigeration and welding process are not performed under the direct supervision of a medical maintenance

manager. The equipment are received back into use after maintenance work has been carried out and the correct use of status card and certificates of serviceability are dully filled up. The technicians provide advice on servicing, repair and modification of the medical equipment. However, adequate time is not fully allocated for the organization to perform preventive maintenance services on a scheduled basis. The institution emphasizes on the responsibilities of equipment user to perform effective maintenance e.g. cleaning. The facility manager guarantees that the operators are properly trained and competent in the use and care of medical equipment. The maintenance shop is centralized with enough storage space and it is adequately furnished. The PUH1 ensures that specialized trades are performed under the direct supervision of medical maintenance manager. Adequate time is allocated for the organization to perform preventive maintenance services as scheduled. However, updated inventories are not effectively placed on site records following every bi-annual planned maintenance cycle. The institution does not emphasize on the responsibilities of equipment user to perform effective maintenance e.g. cleaning. The maintenance manager does not provide advice on servicing, repair and modification of the medical equipment. The storage space for maintenance shop is small, poorly furnished and not centralized. There are also fewer resources available to maintain the hospital equipment. The PUH8 fulfilled maintenance requirements better than most of the public hospitals when interviewed. Corrective and routine preventive maintenance activities are not adequately performed in accordance with the manufacturer's specification or accepted industry standards in most of the hospitals. Updated inventories are mostly not placed on the records file following every bi-annual planned maintenance cycle. The equipment are sent back into use after maintenance work has been carried out. However the correct use of status card and certificates of serviceability are not dully filled up. Refrigeration and welding repairs

are mostly carried out under the direct supervision of medical maintenance managers. The technicians do not provide advice on servicing, repair and modification of the medical equipment also adequate time is not allocated for the organization to perform preventive maintenance services as scheduled. The facility manager does not guarantee that the operators are properly trained and competent in the use and care of medical equipment. This has lead to nurses becoming responsible for the most of the faults. Operators manual for all medical equipment are not necessarily available to the user. The maintenance shop is centralized, however, it does not have enough storage space and it is not adequately furnished. There are no available resources necessary to maintain the hospital equipment.

Although all repairs request are called in by appropriate authorized personnel and each request contains detailed equipment information and possible faults, maintenance managers in PUH6 have no available resources necessary to maintain the hospital equipment. The equipment repairs and testing action are recorded on a service report form and all completed service reports are assigned a result code. Medical equipment are effectively tested for their performance and on electrical safety before a unit is placed into use from temporary storage and also before initial use. The equipment have inspection tags which denote date of inspection and the initials of testing by the technician. They have no ability to send periodic report to the organization when the device fails as indicated in Figure 4.17. All events are recorded and the histories of each equipment in conjunction with the hospital departments are stored well. The performance of scheduled preventive maintenance services on the medical equipment takes priority over routine repairs. Equipment with less than five years are contracted while the in-house team handles the equipment after five year period from the date of installation. The services are completed as scheduled, however, deferment of maintenance activities may be required due to

non-availability of manpower or other extenuating circumstance for instance lack of spare parts. The elements for estimating the cost of repair; direct labour and spares are considered while performing the repairs. The PUH1 has fewer resources available

to maintain the hospital equipment. All repairs request are not necessarily called in by appropriate authorized personnel and each request contains detailed equipment information and identification of possible fault as indicated in Figure 4.16. The equipment repairs and testing action are recorded on a service report form however all completed service reports are not assigned a result code. The medical equipment are not effectively tested on both performance and on electrical safety especially after any accident or damage. The equipment have no inspection tags which denote date of inspection and the initials of testing by the technician. Not all maintenance events are recorded. The history of each equipment in conjunction with the hospital departments are not stored well as indicated in Figure 4.17. The performance of scheduled preventive maintenance services on the medical equipment takes priority over routine repairs. The services are partly completed as per schedule. Deferment of maintenance may be required due to non-availability of manpower or other extenuating circumstance for instance lack of spare parts. The elements for estimating the cost of repair; direct labour and spares are considered while performing the repairs. The majority of hospitals in provincial general hospitals and district hospitals level five have no available resources necessary to maintain the hospital equipment. All repairs request are called in by appropriate authorized personnel and each request contains detailed equipment information and possible faults as indicated in Figure 4.16. The equipment repairs and testing action are recorded on a service report form. However, all completed service reports are not assigned a result code.

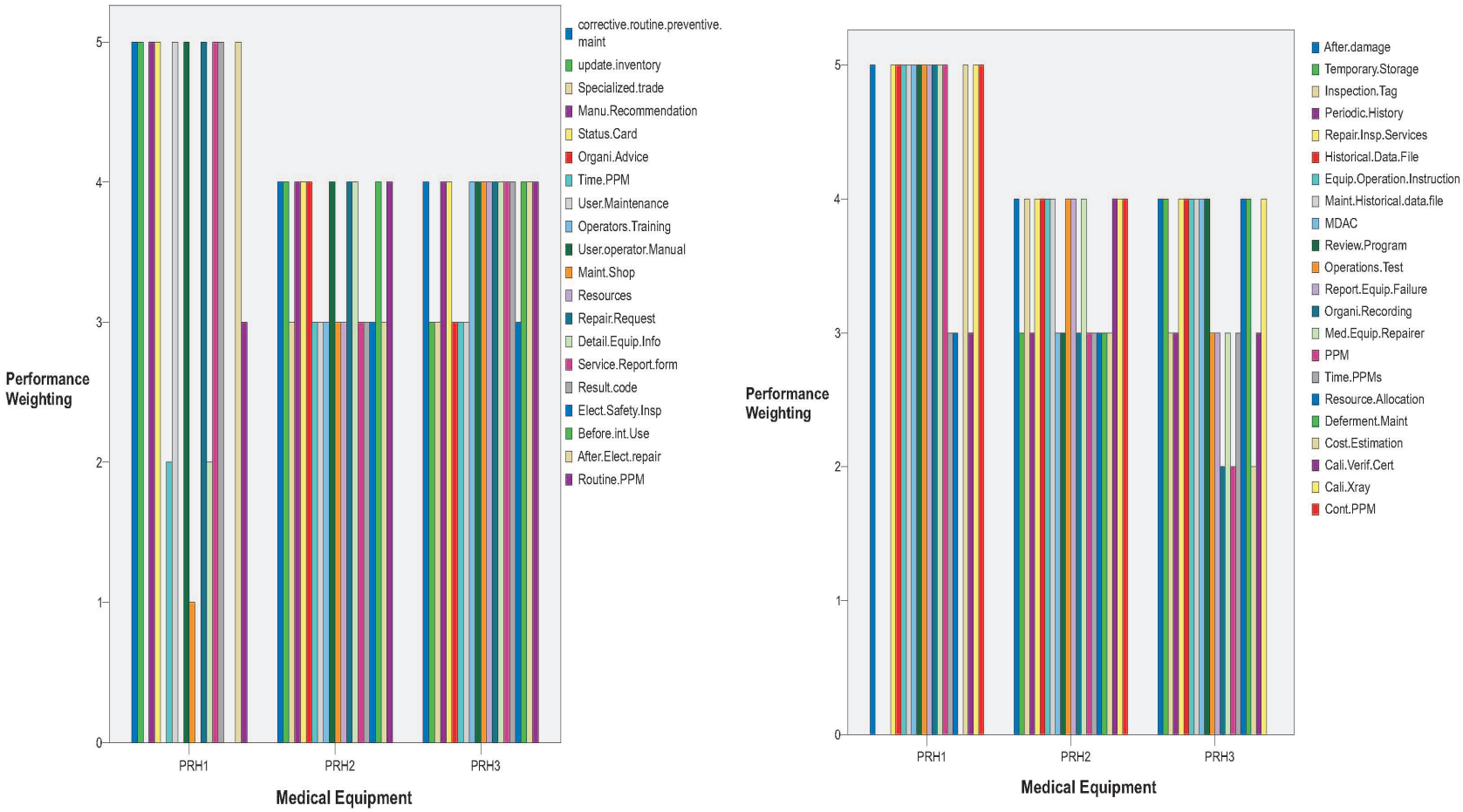


Figure 4.14: The performance weighting of maintenance and repairs in private hospitals.

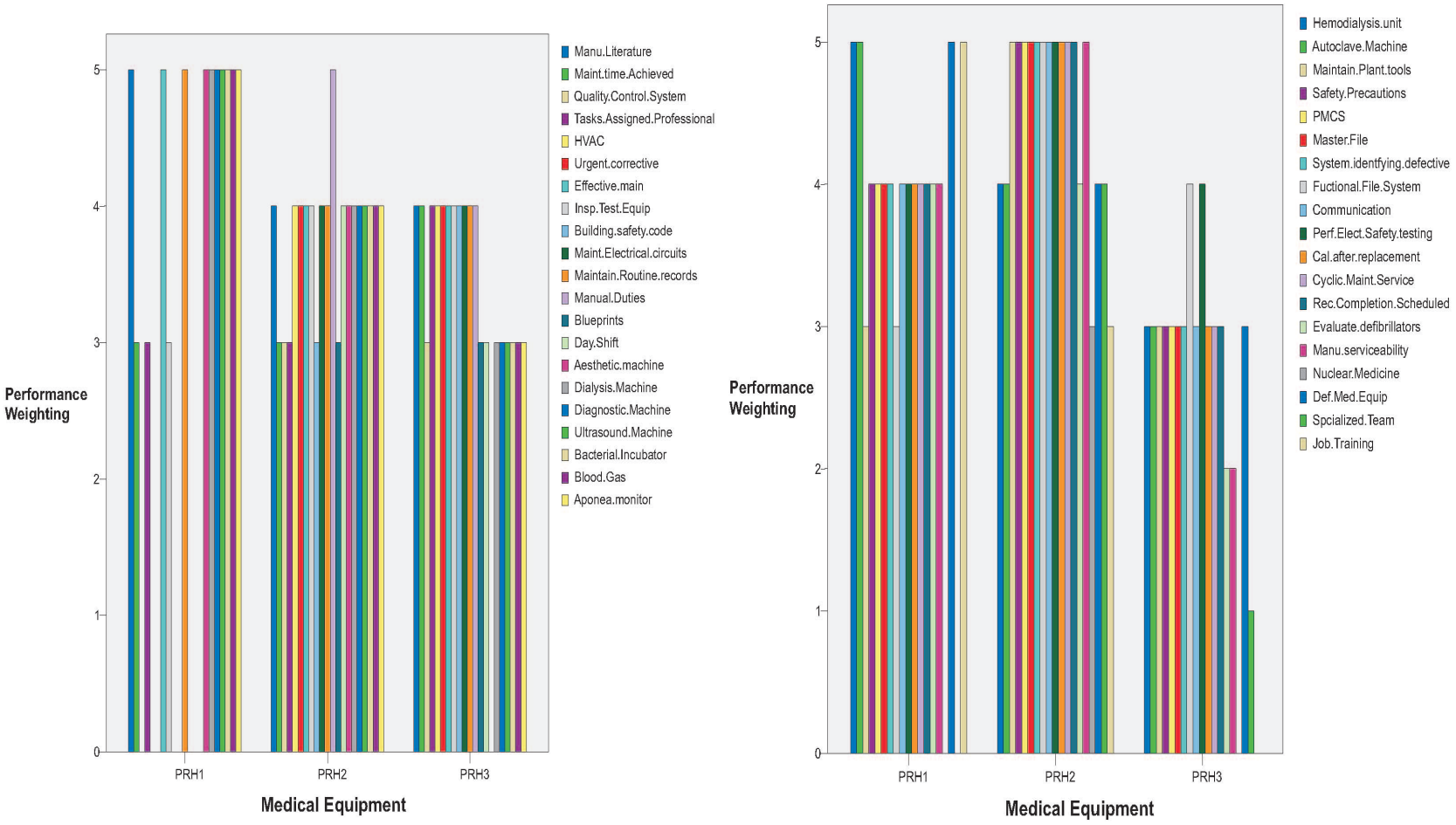


Figure 4.15: The performance weighting of maintenance and repairs in private hospitals.

The maintenance managers from PUH8 and PUH5 ensures that medical equipment are effectively tested for their performance on electrical safety before a unit is placed into use from temporary storage, after any accident or after each electrical repair. The equipment have no inspection tags which denote the date of inspection as well as the initials date of testing by the technician. They have no ability to send periodic report to the organization when the device fails. Repairs and inspection services are not completed in time and they are expensive. The performance of scheduled preventive maintenance services on the medical equipment does not take priority over corrective repairs in most of the hospitals as indicated by Figure 4.17. The services are partly completed as the schedule and time permits. Deferment of maintenance may be required due to non-availability of manpower or other extenuating circumstance for instance lack of spare parts. The elements for estimating the cost of repair, direct labour and spares are some of the factors considered while performing the repairs.

The maintenance managers from PUH6 can repair most of the medical equipment: either diagnostic, therapeutic or laboratory equipment. However most of the specialized equipment including X-ray machines, Nuclear medicine and Magnetic Resonance Imaging (MRI) are contracted to the health care firms. The maintenance department does not have a quality control system for the repair and preventive maintenance activities. The organization has other specialized teams apart from medical engineer, e.g. mechanical and electrical engineers who assist in maintaining hospital equipment and other supporting facilities. Maintenance Medical firms are contracted by the PUH1 to service and calibrate all specialized heating, ventilating and air conditioning equipment and electrical systems. The maintenance managers are able to repair most of the laboratory equipment.

Maintenance managers from other public hospitals are less engaged in contracting medical equipment repair companies to service their machines. They repair most of the medical equipment and assist in maintaining and repairing electrical systems, heating, ventilating, refrigerating and air conditions systems. Maintenance and repairs despite being done by the in-house technicians, they are not adequately practiced. Technical manuals are not fully utilized when repairs are made, maintenance on the medical equipment are not done on the stipulated time frame. The organization has no other specialized teams apart from the medical engineer as indicated in Figure 4.19.

4.6.4 Maintenance and Repairs in Consultant Firms

Figure 4.20 to 4.22 show the performance weighting of maintenance and repair for medical equipment in consultant firms. It is seen from the chart that the CST3 and CST4 are above 3. Most of the consultant maintenance managers offer adequate time to perform preventive maintenance services on a scheduled basis. There are available resources to maintain the hospital medical equipment. These has enabled the maintenance to be performed in accordance with the manufacturer's specification or accepted industry standard as indicated in Figure 4.20. Equipment repair and testing actions are recorded on a service report form, however, all repair request are not necessarily called in by appropriate authorized personnel. Detailed information of the equipment to assist in the fault identification may not be provided. Medical equipment are provided with inspection tags which denote the date of inspection and the initials of testing by the technicians. Routine repairs are not prioritized over scheduled preventive maintenance services on medical equipment. Deferment of maintenance may be required due to non availability of manpower or

other extenuating circumstances. Specialized equipment including X-ray machines, Nuclear medicine and Magnetic Resonance Imaging (MRI) are serviced by the consultant firms when they are still under warrant. Technical manuals are utilized when servicing equipment thus performing all assigned task in a professional manner. The firms provide job training to their staff at national and internationals level.

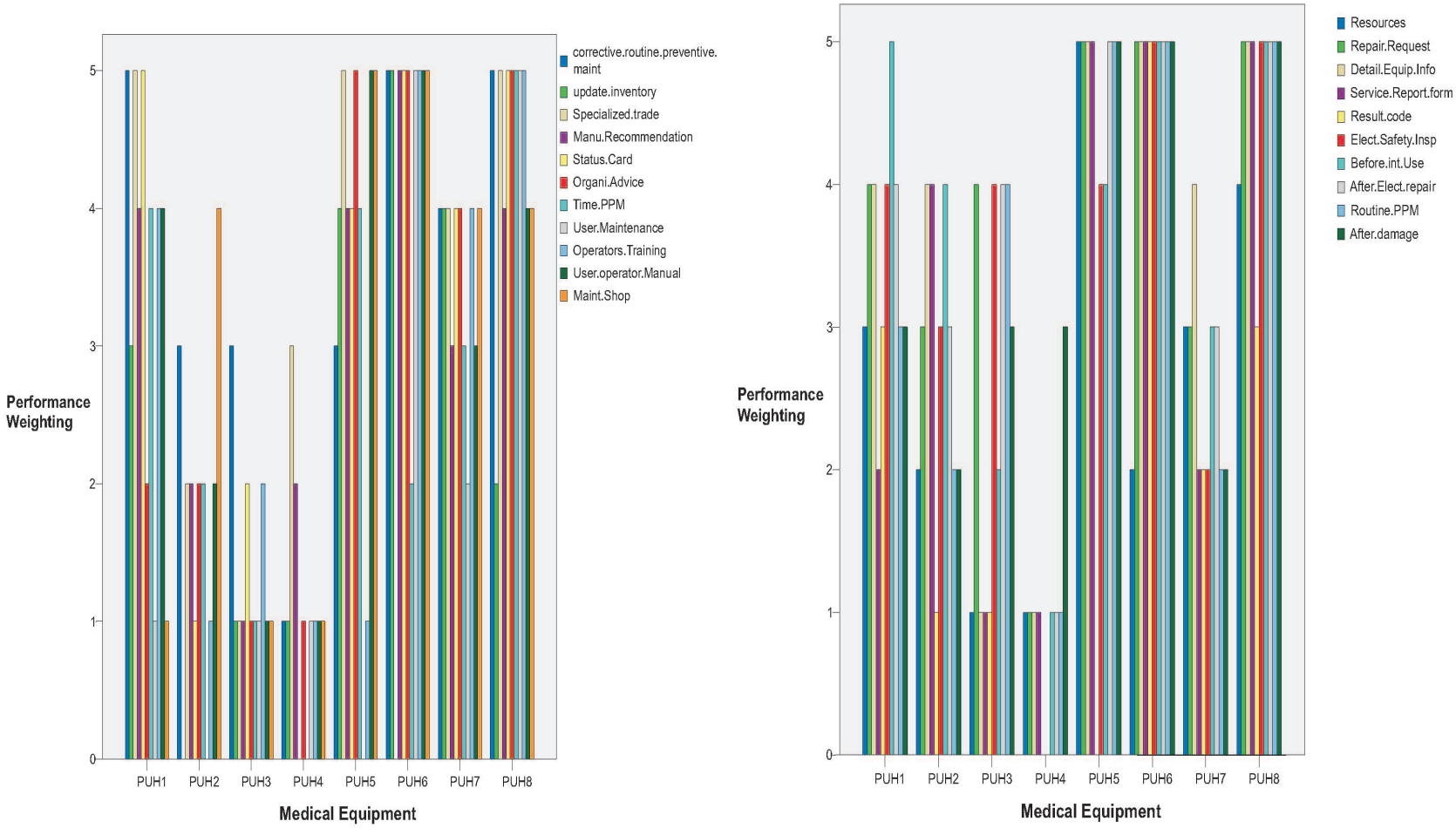


Figure 4.16: The performance weighting of maintenance and repairs in public hospitals.

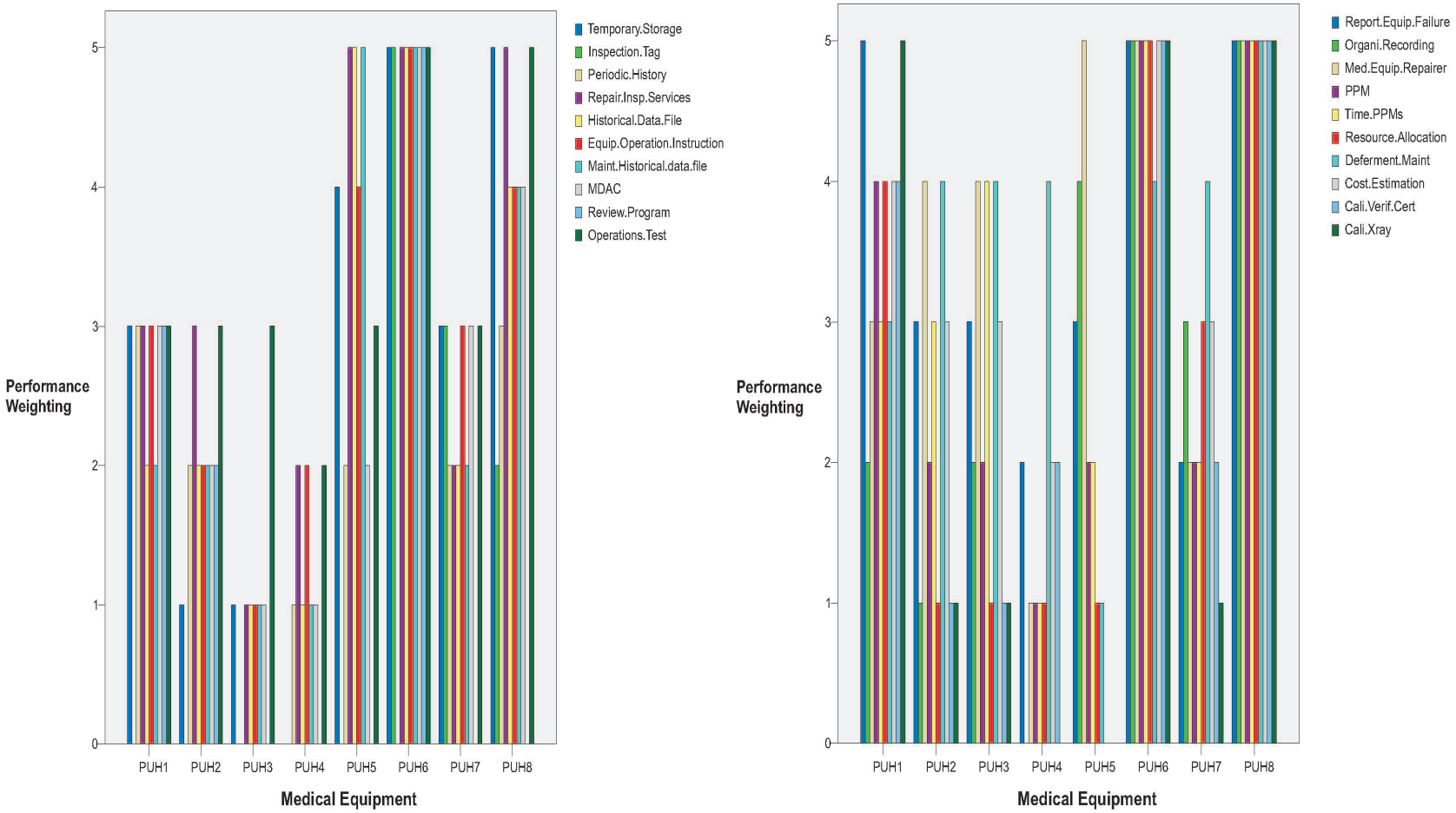


Figure 4.17: The performance weighting of maintenance and repairs in public hospitals.

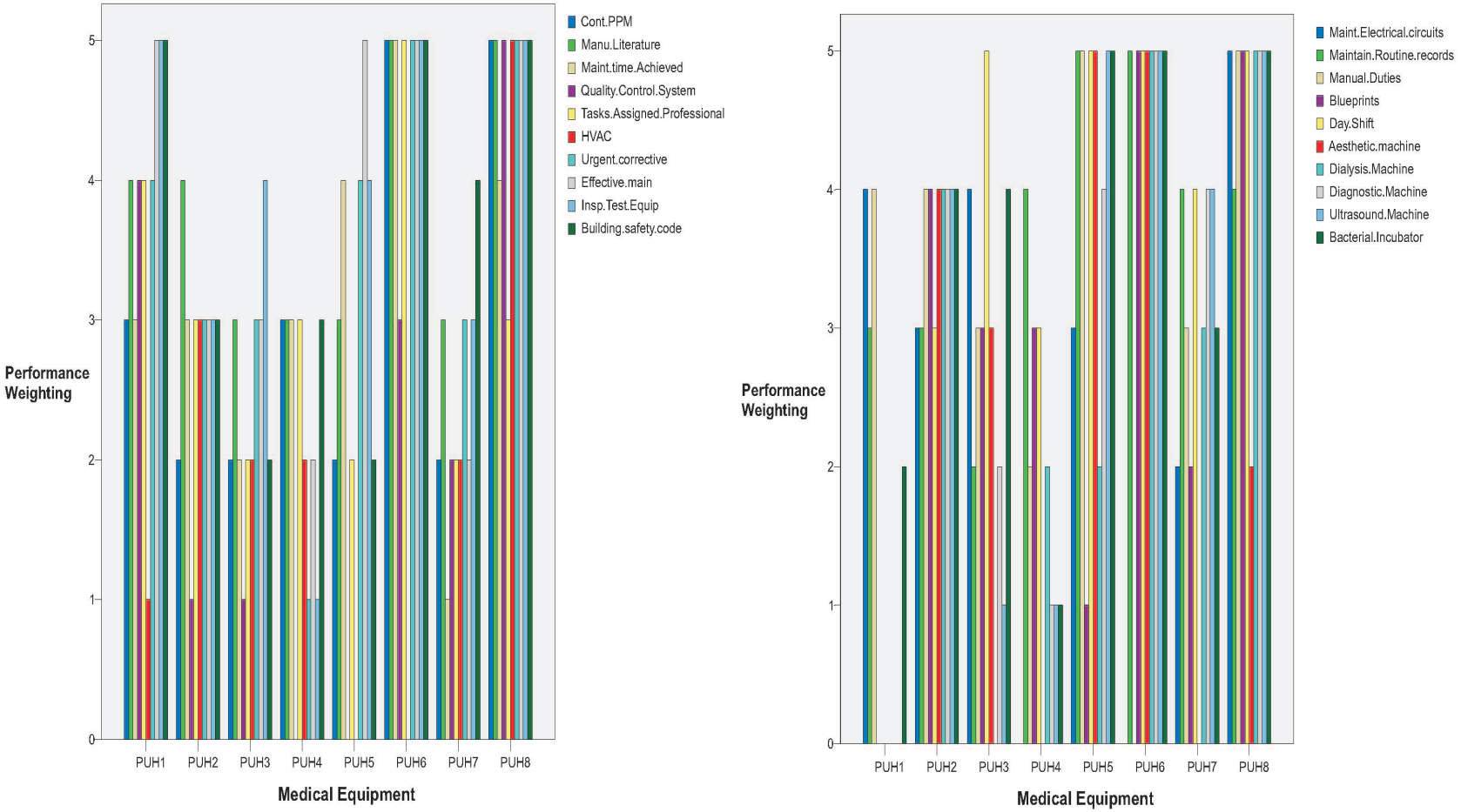


Figure 4.18: The performance weighting of maintenance and repairs in public hospitals.

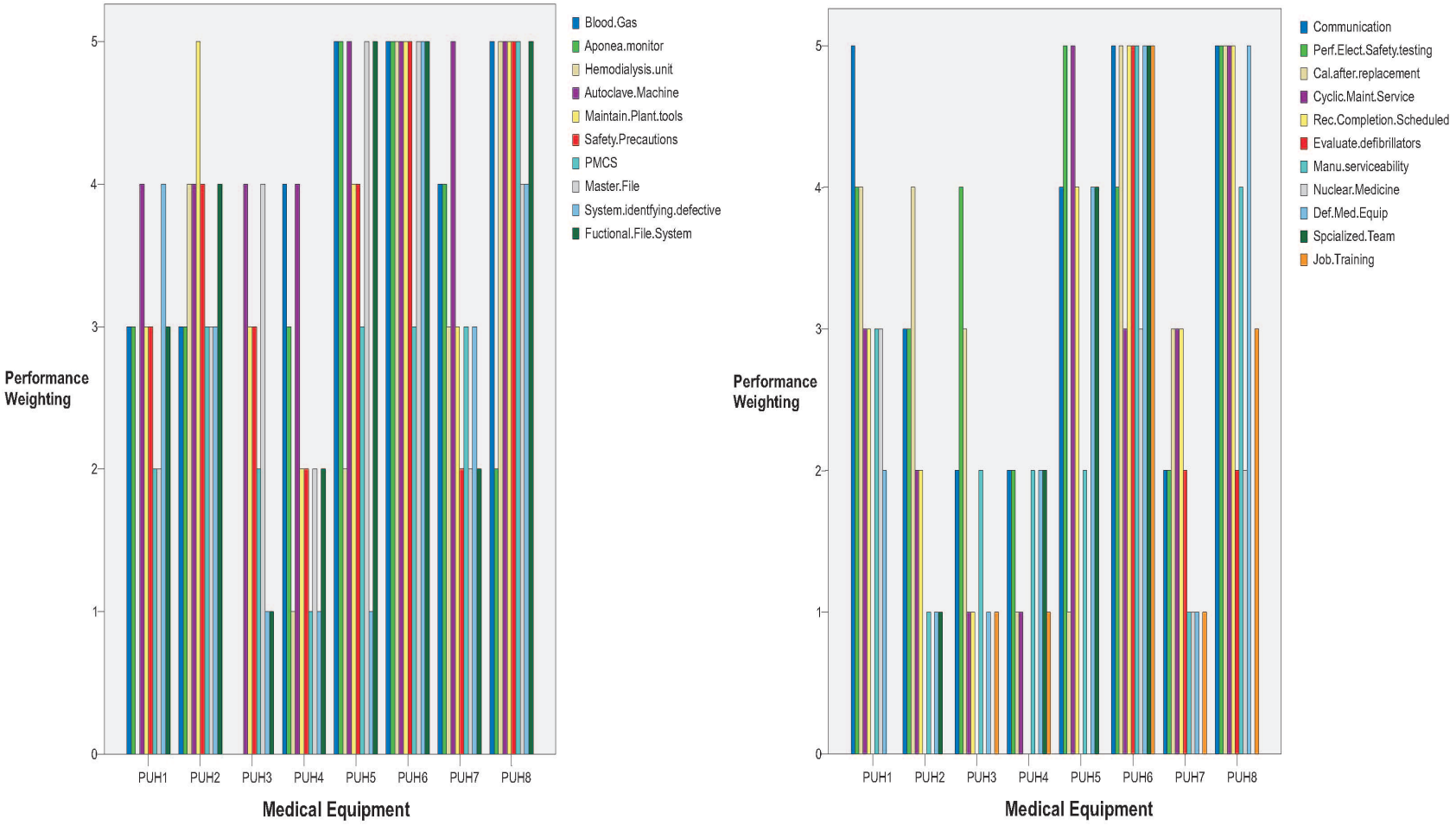


Figure 4.19: The performance weighting of maintenance and repairs in public hospitals.

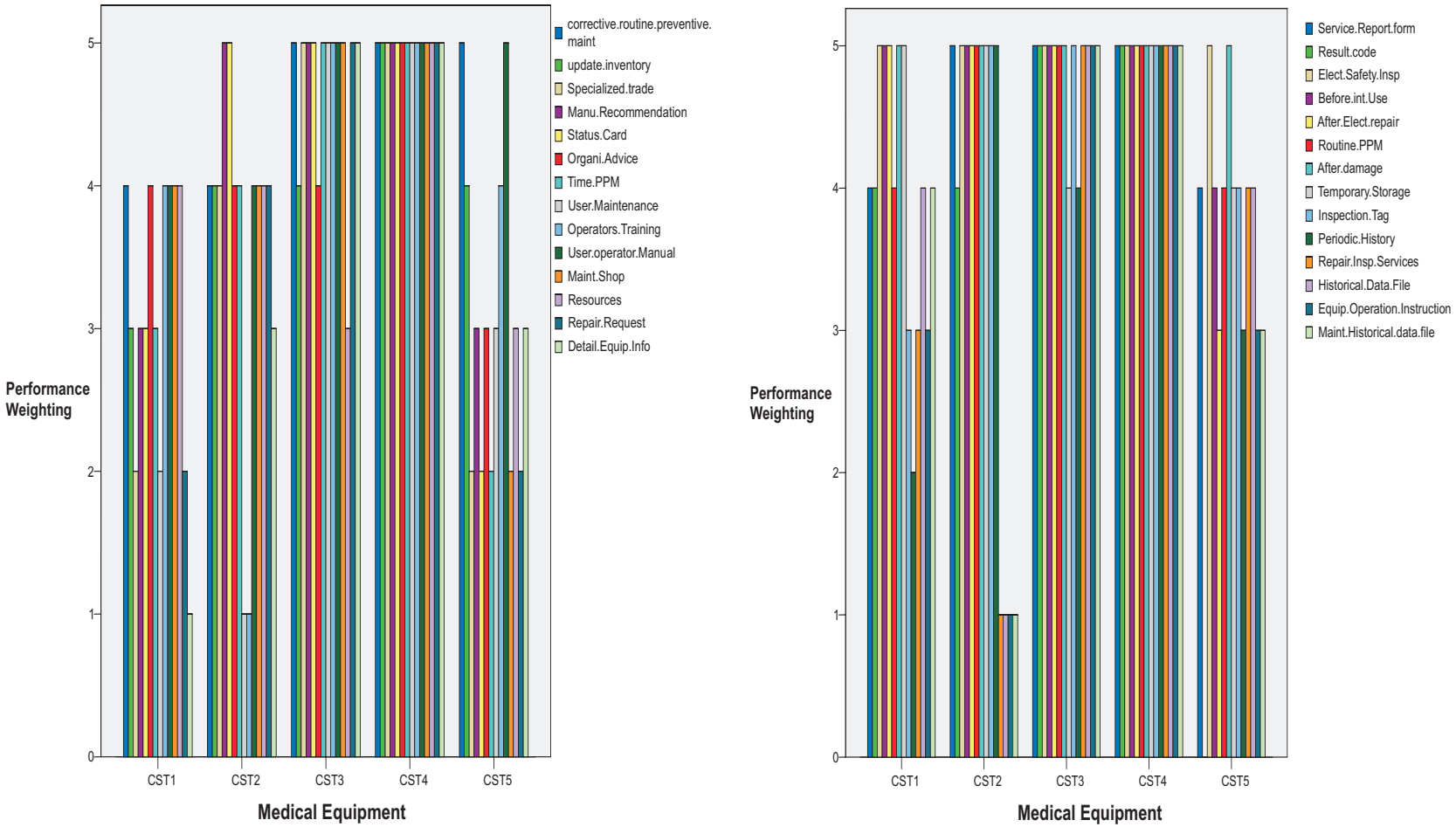


Figure 4.20: The performance weighting of maintenance and repair in consultant firms.

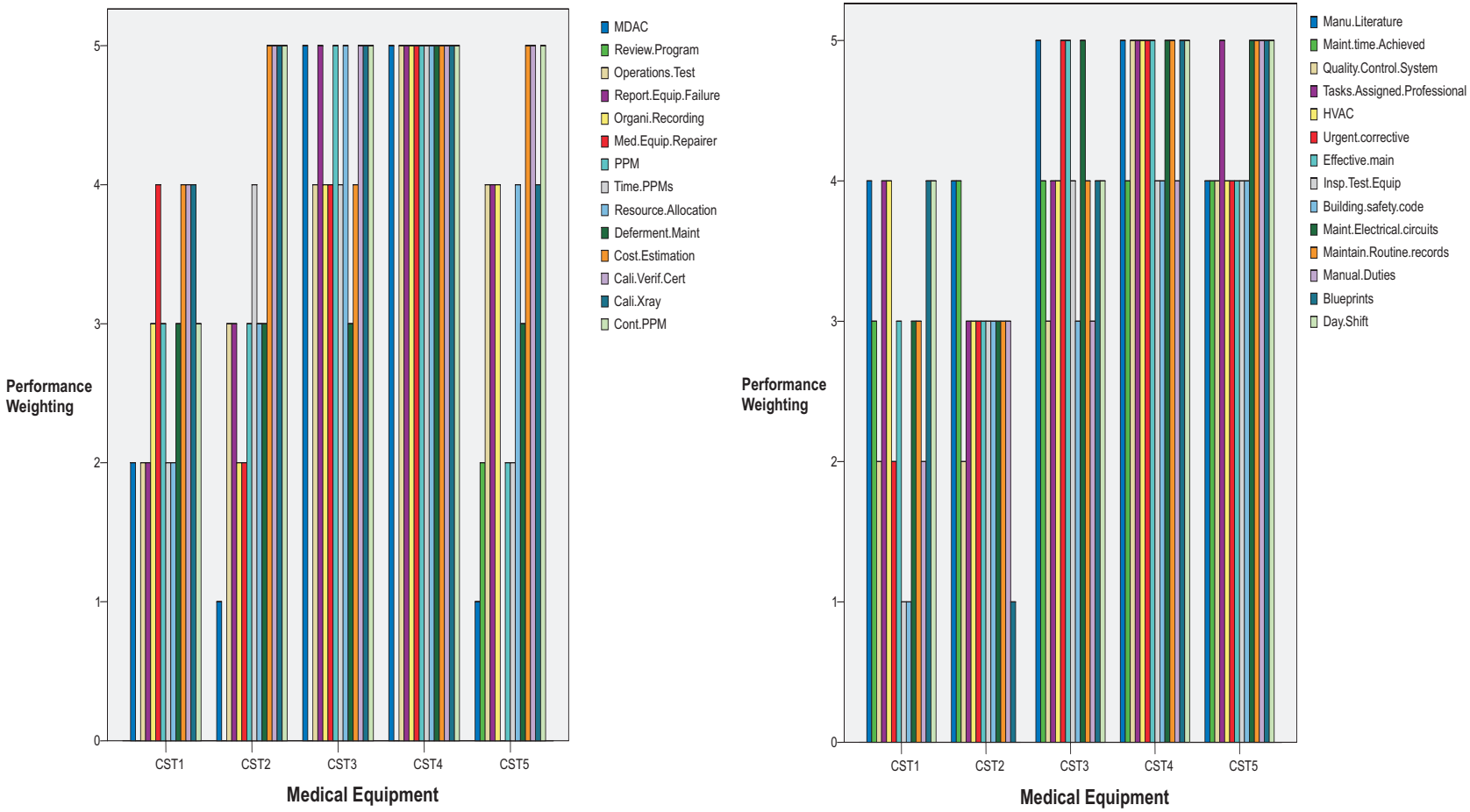


Figure 4.21: The performance weighting of maintenance and repair in consultant firms.

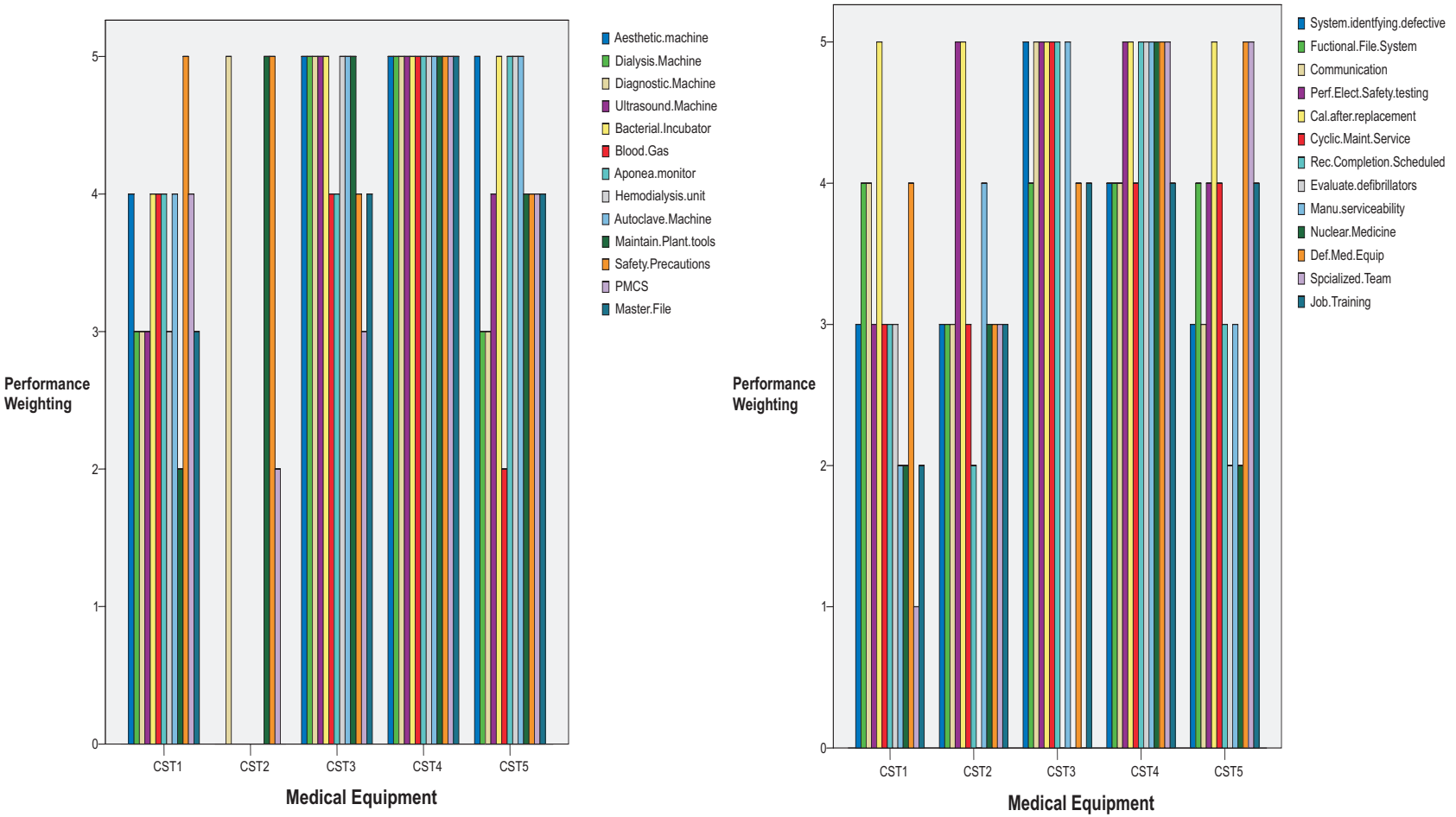


Figure 4.22: The performance weighting of maintenance and repair in consultant firms.

4.6.5 Maintenance and Repairs in Contractor Firms

Figure 4.23 to 4.24 show the performance weighting of maintenance and repair for medical in contracted firms. The CNT1 performs corrective and routine preventive maintenance according to the manufacturing specification. The technicians provide advice on servicing, repair and modification of the medical equipment. Adequate time is fully allocated for the organization to perform preventive maintenance services as scheduled. The institution emphasizes on the responsibilities of equipment user to perform daily maintenance,for example, cleaning. Despite insufficient resources, the scheduled preventive maintenance services are completed as the time permits. Deferment of maintenance may be required due to non availability of manpower or other extenuating circumstances. All equipment contracted to be serviced are effectively maintained with the help of manufacturer's literature and published technical manuals. The firms provide job training to their staff at national and international levels. The combined percentage mean rating for the public, private, consultant and contracted maintenance organization are 58, 69, 75 and 81 per cent respectively as in Figures 4.14 - 4.24. Analysis of combined mean rating reveals that maintenance managers from public hospitals operate at fair position on maintenance and repair of medical equipment. Maintenance not only has a positive impact on the safety and effectiveness of healthcare technology, but also has two important economic benefits;

- it increases the lifetime of equipment and thus helps to save scarce investment resources.
- it enhances the demand for health services. Demand for services availability is crucial of functioning healthcare technology.

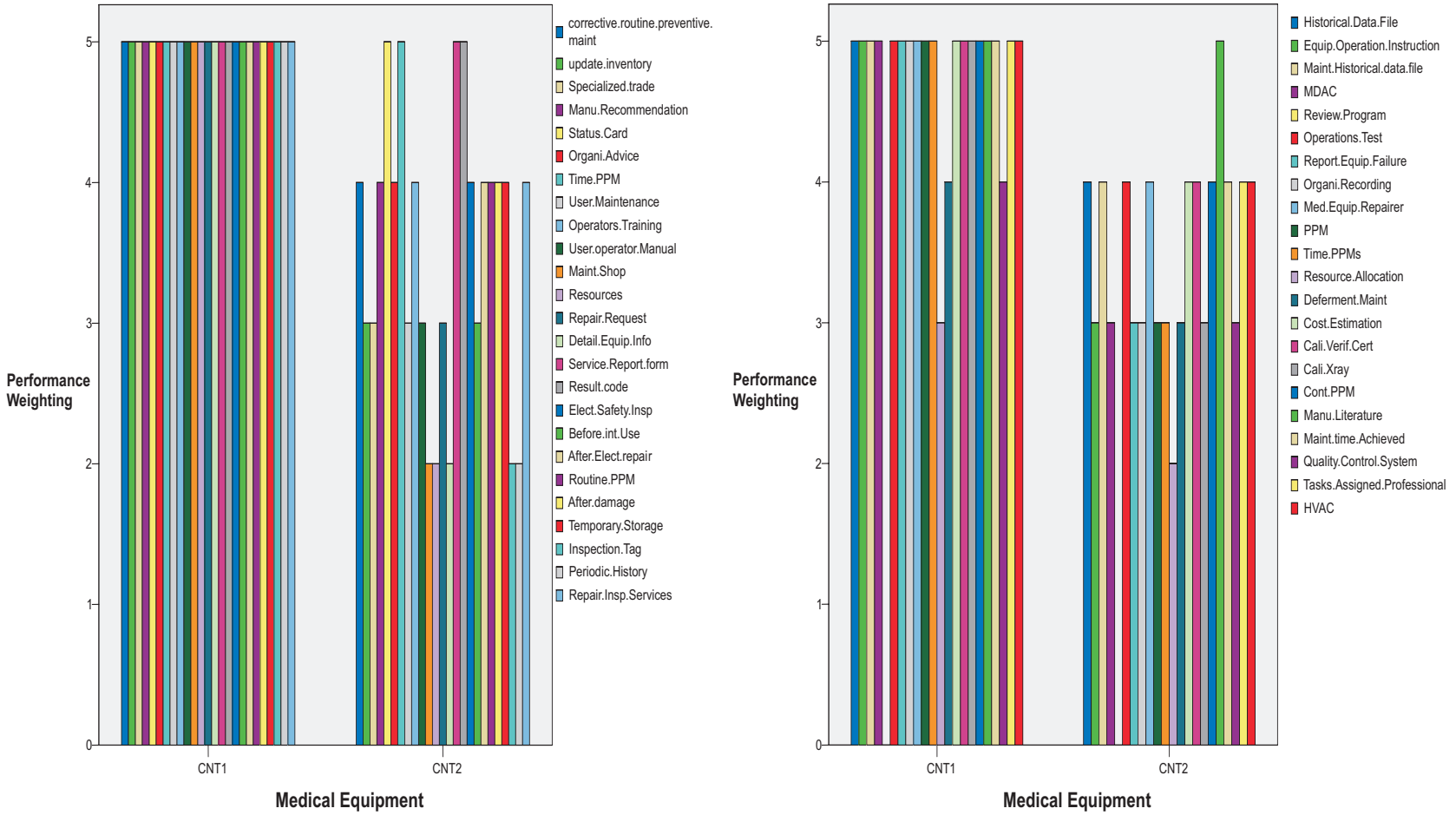


Figure 4.23: The performance weighting of maintenance and repair in contracted firms.

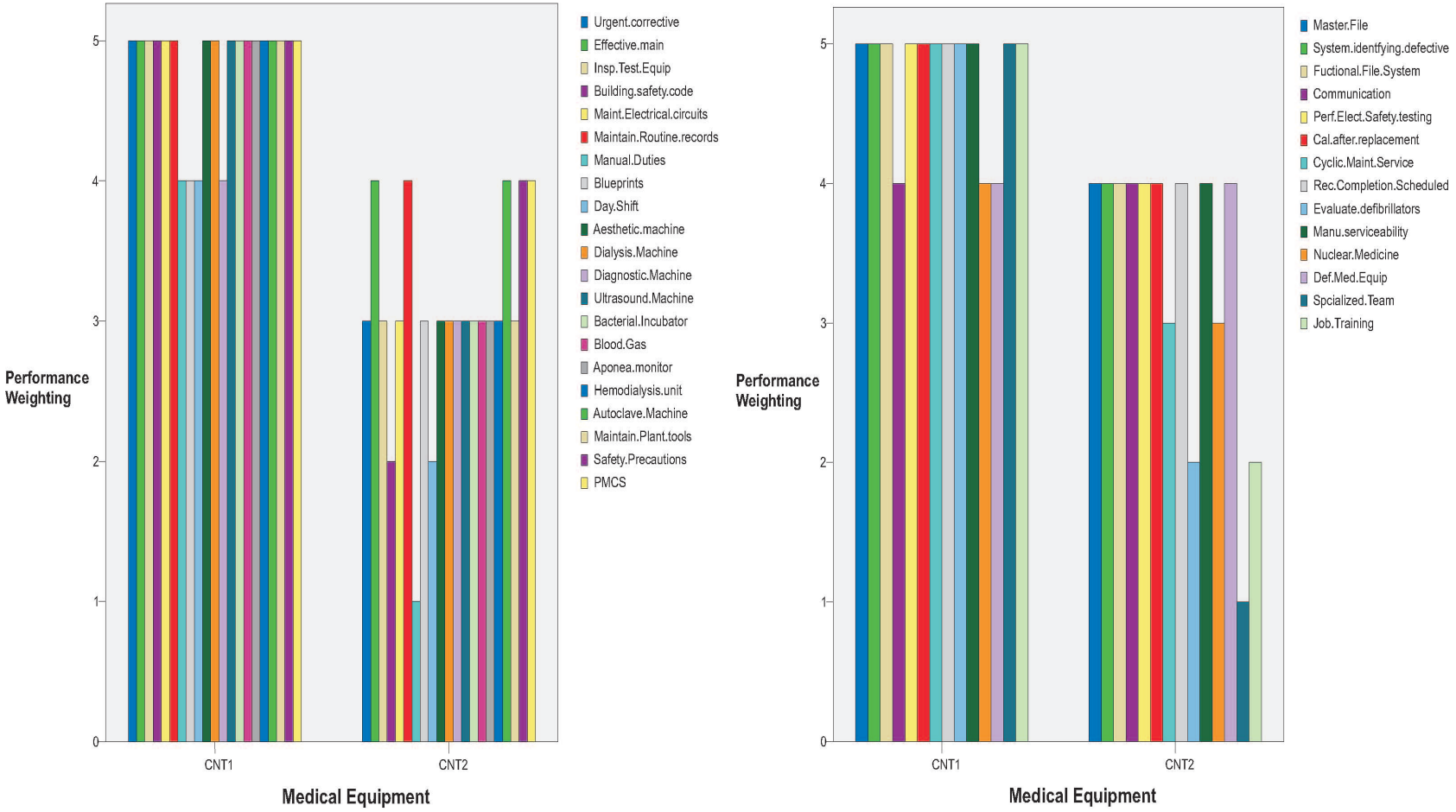


Figure 4.24: The performance weighting of maintenance and repair in contracted firms.

Healthcare that is out of order quickly leads to a decline in demand, which will in turn reduce the income and quality of services of the health facilities. The hospital may lose clients if it is known that malfunctioning of medical equipment, may endanger the health of the patients for instance use of faulty sterilization equipment. Similarly, patients will avoid visiting health facilities which do not possess functioning diagnostic equipment. The maintenance managers are required to accomplish the maintenance for medical equipment in a timely, economical, and professional manner. Due to ever-changing operational requirements and conditions, effective maintenance management requires leadership, planning, organization, assignment of responsibilities, functions and resources, direction, and flexibility. Management of resources (tools, test equipment, standby equipment, spare parts, time, and personnel) should be a daily concern. All resources must be present in sufficient quantity when needed to accomplish the maintenance objective. The following findings needs to be improved by the organizations;

4.6.6 Maintenance Managers in Public Hospital

Updated inventories are mostly not placed on site records following every bi-annual planned maintenance cycle. The correct use of status card and certificates of serviceability is not adequately applied. The technicians do not provide advice among themselves on servicing, repair and modification of the medical equipment. Adequate time is not allocated for the organization to perform preventive maintenance services as scheduled. The facility manager does not guarantee that the operators are properly trained and competent in the use and care of medical equipment. Operators manual for all medical equipment are not necessarily available to the user. The maintenance shop does not have enough storage space and it is not adequately

furnished. There are no available resources necessary to maintain the hospital equipment. The equipment have no inspection tags which denote date of inspection and the initials of testing by the technician and also they have no ability to send periodic report to the organization when the device fails. Repairs and inspection services are not completed in time and often they are expensive. The performance of scheduled preventive maintenance services on the medical equipment does not take priority over corrective repairs in most of the hospitals. Deferment of maintenance may be required due to non-availability of manpower or other extenuating circumstance for instance lack of spare parts. Hospitals have no quality control system for the repair and preventive maintenance. Technical manuals are not fully utilized when repairs are made. Furthermore maintenance on the medical equipment are not done on the stipulated time frame. The institutions do not provide job training to their staff at national and international levels.

4.6.7 Maintenance Managers in Private Hospital

The technicians do not provide advice among themselves on servicing, repair and modification of the medical equipment. Adequate time is not allocated for the organization to perform preventive maintenance services. The facility manager does not guarantee that the operators are properly trained and competent in the use and care of medical equipment. The maintenance shop despite being centralized does not have a secure enough storage space and it is not adequately furnished. There are no adequate resources necessary to maintain the hospital equipment. The medical equipment are not effectively tested on their performance and electrical safety before a unit is placed into use from temporary storage and also before initial use. The equipment have no inspection tags which denote date of inspection and the initials

of testing by the technician and also they have no ability to send periodic report to the organization when the device fails. Deferment of maintenance may be required due to non-availability of manpower or other extenuating circumstance for instance lack of spare parts.

4.6.8 Maintenance Managers in Consultant Firms

All repair requests are not necessarily initiated in by appropriate authorized personnel. Detailed information of the equipment to assist in the fault identification may not be provided. Deferment of maintenance may be required due to non availability of manpower or other extenuating circumstances. For example, most of the firms are not able to evaluate and perform test on defibrillator semi annually using a defibrillator analyzer.

4.6.9 Maintenance Managers in Contractor Firms

The resource allocated to the maintenance activities to the organization does not meet the requirement. Deferment of maintenance may be required due to non availability of manpower or other extenuating circumstances like loss of spare parts.

The findings reveal that the public maintenance managers are ranked as fair at 58 per cent. The other organizations had complied with the most of the standard as they were operating above 60 per cent of the combined mean. The facility maintenance management in the public hospital do not adhere mostly on basic fundamentals when performing maintenance to the equipment; their inventory system are not up to date. Loss of data in the inventory system leads to poor selection of equipment and delay in the maintenance management. Inadequate spare part has led to most of valuable equipment to lay dormant. This has been contributed by poor co-operation of suppliers to hospital management and lack of team work in facility maintenance managers. The planned preventive maintenance is not prioritized leading to failure of the equipment due to undetectable defects, low safety factors, abuse and natural failures. The public maintenance managers do not have adequate information of most of the products thus developing ineffective manuals. Adequate professional training to both operators or users and facility maintenance managers will reduce frequent failure and improve on maintenance management in the public hospital. The faults that occurs suddenly and which are not detected or prevented by PPM measures should not take longer to be repaired. The computer program developed should assist the facility maintenance manager to overcome this challenge. With help of the computer program adequate time is created for repairing the faulty equipment thus improving the efficiency of maintenance management in hospitals.

4.7 Decommissioning and Disposal

4.7.1 Introduction

The parameter is aimed at assessing overall performance of the services provided by the maintenance managers. The medical equipment were assessed based on decommissioning and disposal. The questionnaire had four questions which covered factors in;*control of toxic equipment, equipment usage, effect of hospital management and program for liquidation*

4.7.2 Decommissioning and Disposal in Public Hospitals

Figure 4.25(a) shows the performance weighting of decommissioning and disposal for medical equipment in public hospitals. It is seen from the chart that standard parameters in decommissioning and disposal for the PUH6 and PUH8 are above 3. They have appropriate facilities and program for liquidation. The maintenance manager propose disposal of the aged equipment or unserviceable equipment to the hospital board. The board and the maintenance team are responsible for the final disposal process of the equipment either through the incinerators or the equipment is returned to the manufacturer e.g. Radiation equipment. Toxic equipment infection control companies are fully consulted for the cleaning schedules or procedures before the equipment is disposed. This ensures the control of the environmental pollution when the equipment is discarded. The PUH1 has no appropriate facilities and program for liquidation. However, the management influences the decision of the facilities disposal when requested by the maintenance team. Toxic equipment infection control companies are rarely consulted for the cleaning schedules or procedures

before the equipment is disposed. This encourages the risk of environmental pollution when the equipment is discarded. Provincial and district hospitals level five has no appropriate facilities and program for liquidation, however, the management influences the decision of the facilities disposal when requested by the maintenance team. Toxic equipment infection control companies are rarely consulted for the cleaning schedules or procedures before the equipment is disposed. This contributes to environmental pollution when the equipment is discarded.

4.7.3 Decommissioning and Disposal in Private Hospitals

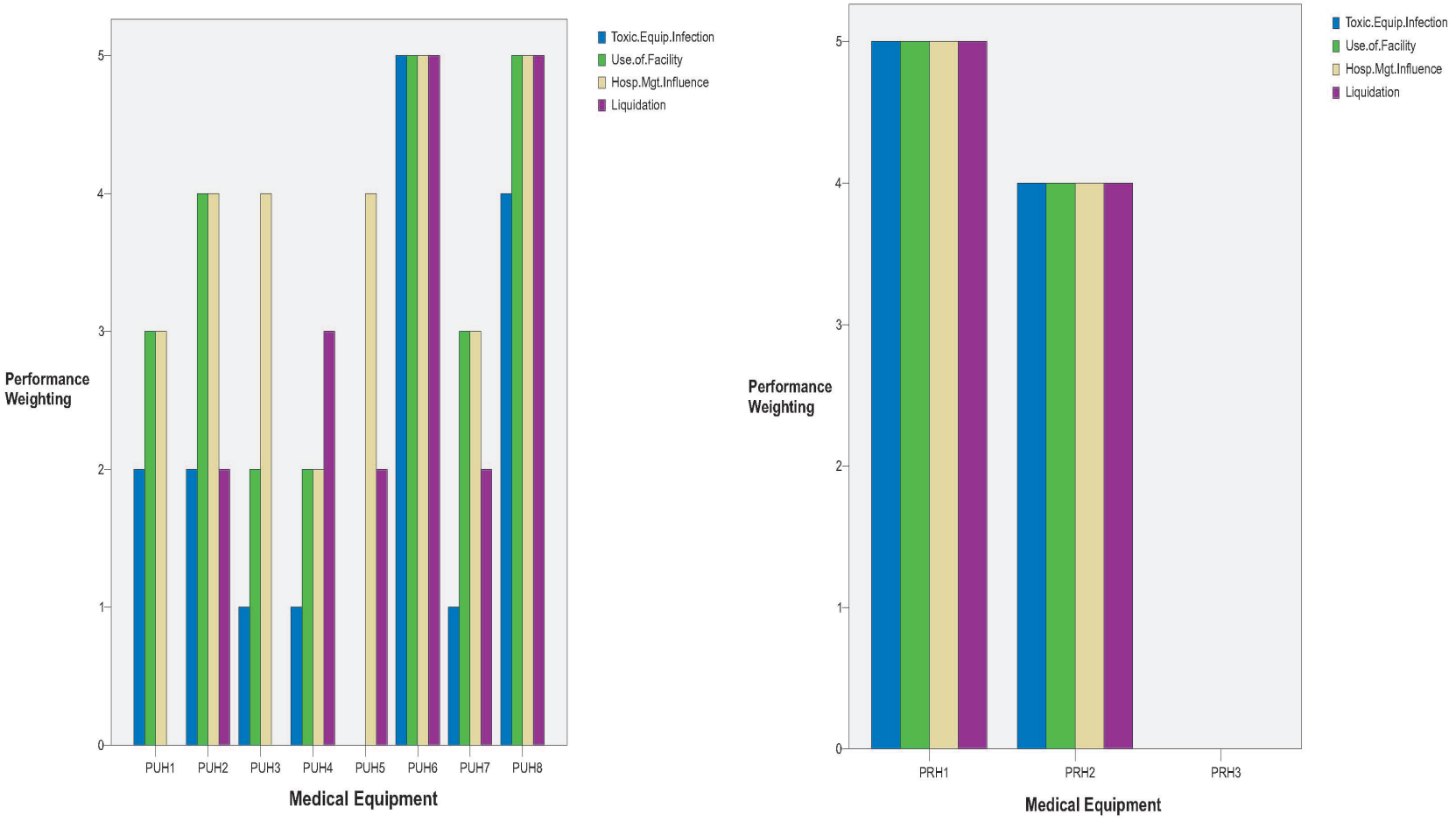
Figure 4.25(b) shows the performance weighting of decommissioning and disposal for medical equipment in private hospitals.It is seen from the chart that standard parameters in decommissioning and disposal for the PRH1 and PRH2 are above 3. The management in the PRH1 and PRH2 influences the disposals of the aged and obsolete facilities. The maintenance managers propose the equipment to be disposed either due to age limit, persistent malfunctioning of the equipment or lack of spares parts. The equipment are sold as scrap metals, auctioned or the equipment is returned to the manufacturers. Toxic equipment infection control companies are fully consulted for the cleaning schedules or procedures before the equipment is disposed. The process controls the risk on environmental pollution when the equipment is discarded. The PRH3, however, has no appropriate facilities and program for equipment disposal.

4.7.4 Decommissioning and Disposal in Consultant Firms

Figure 4.26(a) shows the performance weighting of decommissioning and disposal for medical equipment in consultant firms. Most of the consultant firms have appropriate facilities and program for liquidation. The maintenance managers propose disposal of the aged equipment or unserviceable equipment to the company's management. The management eliminates the specification of the equipment in question from their order list and disposes the returned equipment from the hospitals or other clients through auctions or donating to teaching institutes. Toxic equipment infection control companies are fully consulted for the cleaning schedules or procedures before the equipment is disposed. The CST4 has no appropriate program for liquidation.

4.7.5 Decommissioning and Disposal in Contractor Firms

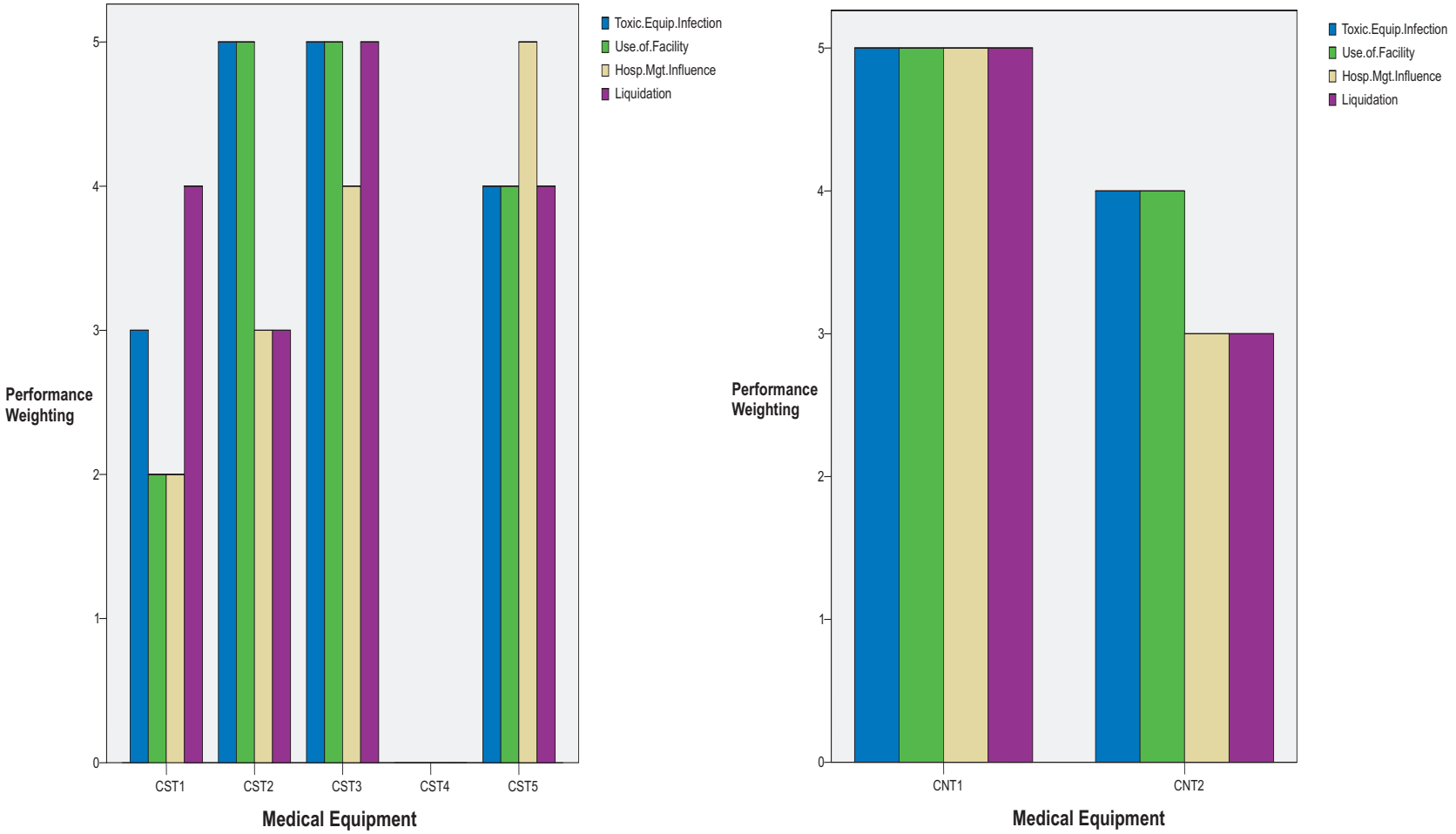
Figure 4.26(b) shows the performance weighting of maintenance and repair for medical equipment in contracted firms. The contracted firms have appropriate facilities and program for liquidation. The maintenance managers propose disposal of the aged equipment or unserviceable equipment to the hospital engineers. The equipment may be sold or auctioned. Toxic equipment infection control companies are fully consulted for the cleaning schedules or procedures before the equipment is disposed. The combined percentage mean rating for the public, private, consultant and contracted maintenance organization are 44, 60, 63 and 85 per cent respectively as in Figures 4.25(a) - 4.26(b). The analysis of combined mean rating reveals that maintenance managers from public hospitals operate at fair position on decommissioning and disposal of medical equipment.



(a) Public

(b) Private

Figure 4.25: The performance weighting of decommissioning and disposal.



(a) Consultant

(b) Contractor

Figure 4.26: The performance weighting of decommissioning and disposal.

The maintenance managers from the institution should be consulted before disposal process is completed. All safety requirements should be adhered to before equipment is released. There are few challenges which needed some improvements in decommissioning and disposal of medical equipment.

4.7.6 Maintenance Managers in Public Hospital

Appropriate program for liquidation of aged and unreliable facilities should be put in place. Companies which disinfect toxic equipment are rarely consulted for the cleaning schedules or procedures before the equipment is disposed.

4.7.7 Maintenance Managers in Private Hospital

Some of the institutions have no appropriate facilities and program for equipment disposal.

4.7.8 Maintenance Managers in Consultant Firms

Some of the institutions have no appropriate facilities and program for equipment disposal. The finding revealed the public maintenance managers were operating in *a fair standard* as per their combined mean of 44 per cent. The organizations dismantle old units to provide spare parts for similar units. They are not included in recommendation for and assistance in disposition of equipment by replacement, refurbishment, upgrading or declared obsolescence. Poor method of acquiring medical equipment contributes to obtaining faulty equipment in the inventory system with unclear warrant. Most of this equipment are disposed due to lack of spares as

they lay dormant occupying space in the maintenance workshop. Decommissioning and disposal process provides an opportunity for cultivating technical innovation using local resources. The disposed equipment may be re-used or recycled by the facility maintenance managers. This will need the facility maintenance managers to be highly trained to manage the equipment effectively. Decommissioned equipment must be deleted to keep the inventory current.

4.8 Programme Development

Hospital maintenance computer program was developed based on the results to improve on the existing facilities maintenance management's performance by the major public and private hospitals in Kenya. The computer program restricts the operator to enter only valid data by checking the validity of data code and data format. The flow chart in figure 4.27 describes the process of the maintenance computer program. Appendix C shows a printout of a hospital maintenance computer program on Blood gas analyzer equipment. The program output requests for the name and serial number of the faulty equipment to be entered; ***Enter Machine Name and Serial Number***. The personnel enters the name and serial number of Blood gas analyzer and its serial number 2200. The screen shot displays the; *Equipment Name, Category of the equipment, Model No., Supplier Company, Department, Last Serviced Date, Next PPM Date* as shown in appendix C.

The program output calls for the fault of the equipment to be entered: ***Enter the Type of Fault***. The fault in the blood gas analyzer is that the equipment displays offscale readings. The problem code for this fault is blood gas: 50004. The computer program screen shot outlines the possible causes of the fault in the equipment immediately the request is fulfilled.

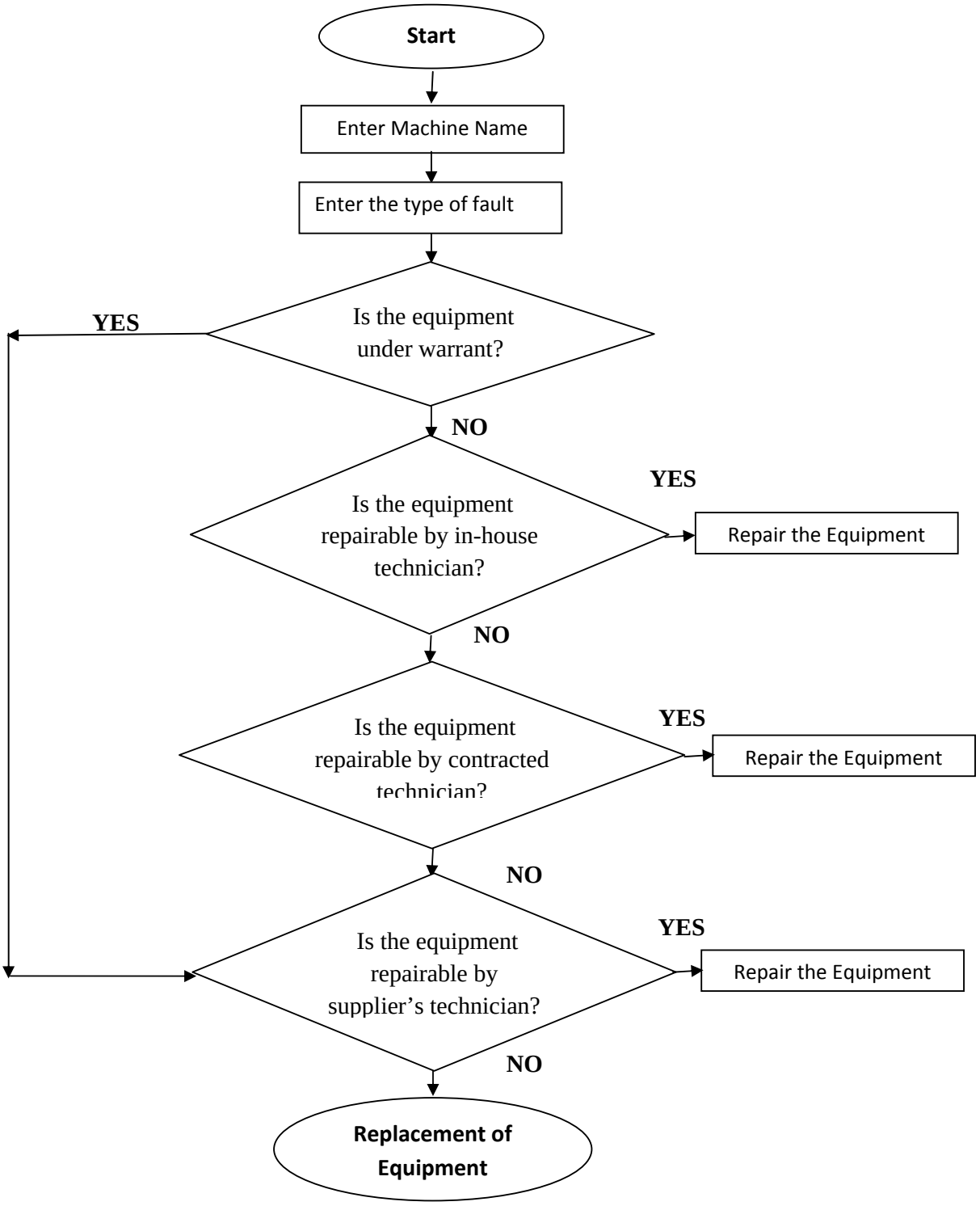


Figure 4.27: Maintenance flowchart program

The program makes decision on which fault in the diagnosed equipment to be repaired by the supplier, the contractor or the in-house technician. To determine whether the equipment is meant to be repaired by the supplier, the program requests for the serial number of the equipment to be entered: ***Enter the Serial Number to determine whether the equipment is under warrant***. When the serial number is entered, the program searches the code in the inventory database. If the serial number is found in the database, the blood gas analyzer is required to be serviced by the supplier technician and thus it is under warranty. However, if the equipment is not in the database and thus not warranted, the in-house technician repairs the equipment as shown in the appendix C.

The program further requests the duration of the blood gas analyzer since the equipment was procured into the hospital: ***Enter the duration in years since the equipment was supplied to the hospital*** . The personnel enters four years to be the period since the equipment was purchased. The screen shot proposes the in-house technician to repair the equipment.

Implementation of the computer program shall improve the maintenance practices by detecting the faults in the shortest duration. In summary the program reports the possible causes of the medical equipment faults and the possible personnel to handle the fault in the equipment. This will reduce the time allocated for the repair of equipment because the information required will be accessed immediately. The facility maintenance management and the quality of patient care will be improved. Paper work and loss of data in the maintenance management will be reduced.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.0.1 Summary

Proper management of medical equipment which includes selection, purchase, installation and maintenance are important for ensuring continued readiness of the service, positive impact on the safety and effectiveness of health services. It increases the lifetime of the equipment and provides information essential for equipment management, especially for deciding about the selection and procurement of equipment when necessary. The specific objective of the research included:

1. To investigate the impact on healthcare in Kenya through equipment maintenance management.
2. Pin-pointing areas where there are short-falls in the hospital's maintenance organizations.
3. To find out the causes of hospital equipment faults in major hospitals in Kenya.
4. To help hospitals in Kenya to manage facilities inventory and maintenance of medical equipment.
5. Development of a computer maintenance program to assist the maintenance management practice and processes.

The finding from the analysis of the data collected revealed that the public maintenance organization does not have proper management of the medical equipment. The other facility managers have excellent procedures to coordinate and oversee the

safe, secure and environmentally sound operations. They also maintain the hospital assets in a cost effective manner which is aimed at long-term preservation of the asset value. The organization fails to assess the new technology when selecting new equipment thus compromising the healthcare and patient safety. Most of the public hospital acquires equipment without proper selection and assessment. Lack of proper involvements of the organization on procurement of the medical equipment has contributed to acquisition of incorrect equipment by the hospitals or equipment which have difficulties in acquiring spares parts for them. The technicians are not well trained and most of them do not proceed for higher learning especially on medical equipment. The institutions do not provide job training to their staff at national and internationals level. They lack proper training therefore are unable to repair most of the modernized equipment. Personnel in hospitals tasked with maintenance and management of equipment are ill equipped with necessary skills.

The performance of scheduled preventive maintenance services on the medical equipment does not take priority over corrective repairs in most of the hospitals. Public hospitals have no quality control system for the repair and preventive maintenance. Technical manuals are not fully utilized when repairs are made, maintenance on the medical equipment are not done on the stipulated time frame. Deferment of maintenance may be required due to non-availability of manpower or other extenuating circumstance for instance lack of spare parts. Hospital lack a computer program to accommodate more equipment. As a result, the above findings lead to the following conclusions:

1. Lack of advance selection assessment system have led to acquisition of inefficient equipment.

2. Poor maintenance and management of equipment have been contributed by

lack of spare parts, inefficient technical staff, use of conditional maintenance rather than PPM.

3. Equipment are used beyond their lifespan leading to likely wrong diagnosis.

4. Implementation of the developed computer programme shall improve the maintenance management of equipment by creating an up to date inventory system, develop a real time solution on who, how and when to repair the equipment.

5. Evaluation of public and private facility managers revealed the poor maintenance management in public hospitals compared to private.

The importance of the research and hence its justification will accrue to the particular hospitals, to the investors of the hospitals and patients. The hospitals will henceforth become effective through efficiency and reliable medical equipment. The shareholders of private hospitals and the government will benefit on increased revenue through more efficient medical equipment. The patients will benefit through correct diagnosis and hence correct treatment prescriptions saving their lives.

5.0.2 Recommendations

The following recommendations need to be considered by all organizations concerned especially public hospital maintenance organization:

1. The organizations to put in place a selection assessment system before acquisition of medical equipment either as a donation, a rental or actual buying.

2. A policy to be implemented to regulate the acquisition of medical equipment based on the remaining lifespan. Medical equipment with less than six years lifespan should not be imported.

3. Availability to medical equipment spare parts should be covered in a written contract before acquisition of the equipment.

4. Employment of experienced engineers from manufacturing companies with external exposure to train the private and public maintenance manager annually.

5. Employment of specialized engineers in public and private hospitals. Probably with a track record in maintenance management systems and who should also posses highly qualification.

6. The organizations to implement the computer program in order to achieve timely regular performance evaluation to detect malfunctioning equipment for timely replacement.

7. The organizations to implement equipment simulators in their respective work stations to determine the safety levels of each repaired equipment.

8. With respect to further study the following should be improved;

    - Computerization of medical equipment to send report in advance when it fails.
    - Computerization of Inventory system to improve in the maintenance activities by assisting the technician simultaneous access equipment history, rapid archive of data as well as vendor information and safety alert.

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APPENDIX A

A.1 QUESTIONNAIRE

EVALUATION OF THE EFFECTIVENESS OF FACILITIES MAINTENANCE MANAGEMENT IN MAJOR PUBLIC AND PRIVATE HOSPITALS IN KENYA

Department of Mechanical Engineering
JKUAT

Introduction

This survey is a part of MSc. study in Industrial Engineering by Mr. David Malombe Mutia, under the supervision of Professor J. M. Kihiu, and Professor S.M.Maranga Department of Mechanical Engineering, JKUAT. The goal of this study is to evaluate the effectiveness of facilities maintenance management in major public and private hospitals in Kenya

This questionnaire is composed of seven parts.

Part I: Technology Assessment and Selection.
Part II: Procurement and Logistics.
Part III: Installation and Commissioning.
Part IV: Training and Skill Development.
Part V: Operation and Safety.
Part VI: Maintenance and Repair.
Part VII: Decommissioning and Disposal.

Benefits of the study to your company

This study aims to evaluate the existing facilities maintenance management practices and processes in major public and private hospitals in Kenya. The results would be used in developing hospital maintenance computer program that will be used in the health care system by the hospital maintenance department. If you are interested in obtaining this research data, please indicate your intention in the last part of the questionnaire, titled Research Interest.

Confidentiality

Your reply will be kept completely confidential.

Filling in the questionnaire

This questionnaire seeks information from the maintenance section, not the entire hospital departments. It is expected that the hospital engineer, service engineer or biomedical engineer will respond to the questionnaire. Recognizing the respondent's valuable time, this questionnaire should require not more than 40 minutes to complete.

Follow-up interviews

This research study also plans to conduct some in-depth case studies by visiting the hospitals and interviewing appropriate persons. Your willingness to allow me carry out the case study will be very much appreciated. For this purpose, please indicate your response in question B in the Research Interest section at the end of the questionnaire.

Contact person

Please return the completed questionnaire to:

David Malombe Mutia
Department of Mechanical Engineering, JKUAT,
P.O Box 62 000 – 00200,
Nairobi.

Should you have any queries, please do not hesitate to contact me at:

E–mail: davi2malombe@yahoo.com
Mobile 0721 – 843 170

SECTION A

General information about the organization

Name of the institution……

Location …….

Address……

Tel No…….

Fax……

Email…….

Contact person……

Please respond to the following questionnaire with sufficient detail to enable suitable evaluation of your organization. All information shall remain confidential.
You may respond on separate sheets, but ***please maintain the allocated numbering*** system.

Section B

EVALUATION OF THE EFFECTIVENESS OF FACILITIES MAINTENANCE MANAGEMENT IN MAJOR PUBLIC AND PRIVATE HOSPITALS IN KENYA

Hospital department or Area: Maintenance of hospital facilities and equipment.

Hospital Facility:_____

Assessor:_____ Date of Assessment _____

Organization:_____

Standard Number	Standard	Compliance in meeting the standard						Total score
		100 %	80 %	60 %	40 %	20 %	0 %	
(i)	**TECHNOLOGY ASSESSMENT AND SELECTION.**							
	Verify Whether:							
	• There is presence of Unique Device Identification (UDI) service charts for the equipment after the purchase.	5	4	3	2	1	0	
	• The organization regularly considers the following measures;							
	✓ Assess the medical equipment performance with reference to the change of environment.	5	4	3	2	1	0	
	✓ Requiring suppliers to undertake environmental measures.	5	4	3	2	1	0	
	✓ Advice the suppliers on ways to reduce the environmental impact on medical equipments.	5	4	3	2	1	0	
	• The following factors are considered on selection of equipment ;							
	✓ Safety.	5	4	3	2	1	0	
	✓ Infection control and decontamination.	5	4	3	2	1	0	
	✓ Effective performance.	5	4	3	2	1	0	
	✓ Financial requirements.	5	4	3	2	1	0	
	✓ Full life costs.	5	4	3	2	1	0	
	✓ Compatibility with existing equipment.	5	4	3	2	1	0	
	✓ Reliability.	5	4	3	2	1	0	
	✓ Availability of maintenance service.	5	4	3	2	1	0	
	✓ Installation requirements.	5	4	3	2	1	0	
	✓ Spare parts.	5	4	3	2	1	0	
	✓ User and maintenance training	5	4	3	2	1	0	

(ii)	**PROCUREMENT AND LOGISTICS.** **Verify Whether;**							
	• A purchase order is provided to the service technician prior to leaving the facility.	5	4	3	2	1	0	
	• The organization maintains an up to date inventory of all equipment within the department.	5	4	3	2	1	0	
	• The hospital team participates in equipment selection arrangements as required.	5	4	3	2	1	0	
	• There are standard operating procedures in place for the equipment.	5	4	3	2	1	0	
	• The organization is responsible for "user equipment servicing" and ensures that arrangements are made to have this carried out to the equipment manufacturer's recommendations.	5	4	3	2	1	0	
	• The organization makes pre-purchase evaluations of equipment at the written request to the vendor.	5	4	3	2	1	0	
	• Evaluation of equipment is confined to: ✓ Construction quality. ✓ Mechanical reliability. ✓ Ease of maintenance. ✓ Compatibility with existing systems. ✓ Required agency approvals. ✓ Requirements of installation, environmental, and safety issues. ✓ Support requirement after warranty expiration. ✓ Development of equipment in-service training.	5 5 5 5 5 5 5 5	4 4 4 4 4 4 4 4	3 3 3 3 3 3 3 3	2 2 2 2 2 2 2 2	1 1 1 1 1 1 1 1	0 0 0 0 0 0 0 0	
	• The organization has plans to invest in medical equipment and other facilities.	5	4	3	2	1	0	
	• The organization has appropriate facilities and program for procurement.	5	4	3	2	1	0	
	• The hospitals general administrative planning includes the purchase and replacement of equipment for all basic units?	5	4	3	2	1	0	

(iii)	**INSTALLATION AND COMMISSIONING.** Verify whether all equipments accepted into service by the departmental engineer;							
	• Are always safe to use and complies with all relevant standards.	5	4	3	2	1	0	
	• Meets specified performance criteria and is undamaged.	5	4	3	2	1	0	
	• Matches the order and arrives complete with accessories.	5	4	3	2	1	0	
	• Are registered on the division inventory and has been given asset identification.	5	4	3	2	1	0	
	• Are placed on a routine maintenance programme.	5	4	3	2	1	0	
	• Have the following items as part of any equipment order: ✓ Two copies of operators manual. ✓ One copy of service/technical manual. ✓ Manufacturer/vendor supplied in-service training.	5 5 5	4 4 4	3 3 3	2 2 2	1 1 1	0 0 0	
	Verify whether; • New or overhauled equipment is commissioned before use.	5	4	3	2	1	0	
	• A statement appears on all equipment quotes to assure compliance with applicable standards and codes.	5	4	3	2	1	0	

(iv)	**TRAINING AND SKILL DEVELOPMENT.** **Verify Whether;**							
	• The organization is capable of handling pre-programmed or user-configurable profiles medical devices based on use-context.	5	4	3	2	1	0	
	• The organization has computerized medical maintenance system (CMMS) reporting device usage parameters, event logs, and other information required to predict necessary preventative maintenance.	5	4	3	2	1	0	
	• The maintenance system has the ability to analyze the data streams to predict calibration problems.	5	4	3	2	1	0	
	• In-service training is provided on medical equipment.	5	4	3	2	1	0	
	✓ On all new equipment purchase.	5	4	3	2	1	0	
	✓ On all rental/loaner equipment (different from devices in use).	5	4	3	2	1	0	
	✓ On all equipment involved in frequent "operator errors" and as indicated by service summaries.	5	4	3	2	1	0	
	✓ With all new employees.	5	4	3	2	1	0	
	✓ With all employees annually							
	• In-service training is conducted by:	5	4	3	2	1	0	
	✓ Manufacturer or vendor.	5	4	3	2	1	0	
	✓ Nursing Education.	5	4	3	2	1	0	
	✓ Medical Equipment Service, In. = technicians							
	• The organization maintains equipment manuals and training guides for each piece of equipment in use.	5	4	3	2	1	0	
	• Facility managers document orientation and annual review of employee proficiency in the use and safety of each type of device.	5	4	3	2	1	0	
	• The organization maintains continuing education & training on equipment serviced by medical technicians.	5	4	3	2	1	0	
	• The organization has been given training; has competence in the operation, maintenance and cleaning of the equipment	5	4	3	2	1	0	
	• Equipment operators are trained and proficient on all equipment for which they are responsible.	5	4	3	2	1	0	

(v)	**OPERATION AND SAFETY.** **Verify Whether;**							
	• The organization is properly equipped for the maintenance purposes.	5	4	3	2	1	0	
	• There are plans for the purchase and maintenance of equipment.	5	4	3	2	1	0	
	• The hospital has equipment of high quality needed to carry out its function	5	4	3	2	1	0	
	• The hospital keeps current inventories of the equipment and its condition in its various units?	5	4	3	2	1	0	
	• The assignment of responsibility for maintenance are clearly documented	5	4	3	2	1	0	
	• There is a clear plan for maintenance as well a s follow-up and analysis of faulty medical equipments	5	4	3	2	1	0	
	• The organization adheres to safety procedures during maintenance operations.	5	4	3	2	1	0	
	• The organization brings unsafe equipment operations to the attention of user/operator personnel and their supervisors, by identifying defective equipment and alerting potential users.	5	4	3	2	1	0	
	• Are training programs related to health and safety of the equipment given?	5	4	3	2	1	0	
	• Is there a manual on general Health and safety?	5	4	3	2	1	0	
	• Faulty medical equipments are accessible by the maintenance team.	5	4	3	2	1	0	
	• Each piece of equipment listed in the medical equipment inventory has written testing procedures to test for operation and safety integrity.	5	4	3	2	1	0	
	• The procedures are developed from manufacturer's equipment service manuals and industry-wide accepted testing criteria.	5	4	3	2	1	0	

(vi)	**MAINTENANCE AND REPAIR.** **Verify Whether;**							
	• All corrective and routine preventive maintenance is performed in accordance with the manufacturer's specifications or accepted industry standards.	5	4	3	2	1	0	
	• An updated inventory is placed on-site records following every bi- annual Planned Maintenance cycle.	5	4	3	2	1	0	
	• Specialized trade requirements for medical equipment, i.e. welding and refrigeration support are performed under the direct supervision of a medical equipment maintainer.	5	4	3	2	1	0	
	• Each item of equipment is maintained in accordance with the manufacturer's recommendations and reflects the interest of the user.	5	4	3	2	1	0	
	• The equipment is received back into use after maintenance work has been carried out and the correct use of status card and certificates of serviceability is applied.	5	4	3	2	1	0	
	• The organization provides advice on servicing, repair and modification of the equipment.	5	4	3	2	1	0	
	• Adequate time is allocated for the organization to perform preventive maintenance services on a scheduled basis.	5	4	3	2	1	0	
	• The hospital publishes and makes compulsory a directive, emphasizing the responsibilities of equipment user to perform effective operator maintenance e.g. cleaning.	5	4	3	2	1	0	
	• There is accountability of facility managers to ensure operators are properly trained and competent in the use and care of medical equipment.	5	4	3	2	1	0	
	• The equipment's operator manuals for all medical equipments are on hand and readily available to the user.	5	4	3	2	1	0	
	• The maintenance shop is centrally located as possible, be accessible, and has a secure storage space for repair parts, supplies, tools, test equipment, and equipment awaiting repair and/or parts.	5	4	3	2	1	0	

	• There are available resources (i.e. tools, parts, and test equipment) necessary to maintain the hospital medical equipment.	5	4	3	2	1	0	
	• All repair requests are called in by appropriate authorized personnel.	5	4	3	2	1	0	
	• Each request includes detailed equipment information and fault identification.	5	4	3	2	1	0	
	• Equipments repair and testing actions are recorded on a service report form	5	4	3	2	1	0	
	• All competed service reports are assigned a result code	5	4	3	2	1	0	
	• All electrical safety inspections are made in compliance with standards set forth.	5	4	3	2	1	0	
	• medical equipments are tested for performance and electrical safety:							
	✓ Before initial use.	5	4	3	2	1	0	
	✓ After each electrical repair.	5	4	3	2	1	0	
	✓ As part of each routine preventive maintenance inspection.	5	4	3	2	1	0	
	✓ After any accident of damage, real or suspected.	5	4	3	2	1	0	
	✓ Before a unit is placed into use from temporary storage	5	4	3	2	1	0	
	• Medical equipments have inspection tags which denote date of inspection and the initials of testing by the technician.	5	4	3	2	1	0	
	• The medical equipments have the ability to send periodic or a periodic history to the organization when the devices fail. This includes device event logs, change logs, alarm events, and power/boot-up statistics.	5	4	3	2	1	0	
	• The facility manager:							
	✓ Assures repair and inspection services are completed in a timely and in cost effective manner.	5	4	3	2	1	0	
	✓ Provide and maintain historical data files on equipment and vendors.	5	4	3	2	1	0	
	✓ Maintain equipment operation instructions.	5	4	3	2	1	0	
	✓ Assure safe Medical Device Act Compliance.	5	4	3	2	1	0	
	✓ Annually review program effectiveness							

	• The user: ✓ Perform equipment operations tests prior to use. ✓ Report equipment failures or operation aberrations in time.	5 5	4 4	3 3	2 2	1 1	0 0	
	• The organization records all events and builds a history of each item of equipment in conjunction with the hospital departments.	5	4	3	2	1	0	
	• Defective/unserviceable medical equipment is repaired or serviced by hospital attached medical equipment repairers.	5	4	3	2	1	0	
	• The performance of scheduled preventive maintenance services on medical equipment takes priority over routine repairs.	5	4	3	2	1	0	
	• Scheduled preventive maintenance services are completed as the mission and time permits.	5	4	3	2	1	0	
	• Resources are allocated as required to perform the scheduled maintenance services at required period.	5	4	3	2	1	0	
	• Deferment of maintenance may be required due to non-availability of manpower or other extenuating circumstances.	5	4	3	2	1	0	
	• The elements for estimating the cost of repair; Direct labor, Direct materiel, Packaging and freight and Miscellaneous are considered while performing the repair.	5	4	3	2	1	0	
	• The Calibration, Verification, Certification services are performed on the identified medical equipments.	5	4	3	2	1	0	
	• Calibration on x-ray systems at the frequency are performed as specified by the manufacturer.	5	4	3	2	1	0	
	• The contractor performs scheduled maintenance services and calibration for all x-ray equipment, including computer tomography (CT).	5	4	3	2	1	0	
	• The manufacturer's literature and published technical manuals is used by the medical equipment repairer when performing a Technical Inspection for condition coding and repair eligibility.	5	4	3	2	1	0	
	• The maintenance ability time is achieved.	5	4	3	2	1	0	
	• The identified hospitals have a Quality Control System for the repair and preventive maintenance activities?	5	4	3	2	1	0	

	Verify whether the organization;							
	• Performs all assigned tasks in a professional manner to reflect The highest integrity of the Engineering Department.	5	4	3	2	1	0	
	• Assists in maintaining and repairing HVAC controls an Associated equipment to maximize efficiency levels in all Environmentally controlled areas.	5	4	3	2	1	0	
	• Performs urgent corrective, routine and requisitioned repairs of electrical, mechanical and plumbing systems as required.	5	4	3	2	1	0	
	• Performs maintenance on equipment and systems as required.	5	4	3	2	1	0	
	• Assists in maintaining electrical wiring and emergency generator systems. Inspects and tests equipment/systems.	5	4	3	2	1	0	
	• Performs preventive maintenance duties to all physical structures of hospital and complies with all building safety codes. This is to include facility equipment and associated controls.	5	4	3	2	1	0	
	• Assists in replacing, installing, repairing and testing electrical circuits, equipment, appliances and lighting systems as required.	5	4	3	2	1	0	
	• Maintains routine records of all inspections, preventive maintenance and repairs performed on any equipment or system.	5	4	3	2	1	0	
	• Performs manual duties as requested (i.e., moving supplies or furniture, replacing light bulbs, removing trash or scrap material).	5	4	3	2	1	0	
	• Reads blueprints, interprets instructions and prepares specifications.	5	4	3	2	1	0	
	• Works day, evening or night shift as assigned.	5	4	3	2	1	0	
	• Has a thorough knowledge of the following equipments	5	4	3	2	1	0	
	✓ An aesthetics Machines.	5		3	2	1	0	
	✓ Dialysis Machines.	5	4	3	2	1	0	
	✓ Diagnostic X-ray Machine.	5	4	3	2	1	0	
	✓ Ultrasound Equipment.	5	4	3	2	1	0	
	✓ Bacterial Incubators.	5	4	3	2	1	0	
	✓ Blood gas/pH Analyzers.	5	4	3	2	1	0	
	✓ Apnea Monitors (Neonatal).	5	4	3	2	1	0	
	✓ Hemodialysis Units.	5	4	3	2	1	0	
	✓ Autoclaves Machine							

	• Has a thorough knowledge of how to use and maintain plant tools and equipments.	5	4	3	2	1	0	
	• Have the knowledge and observance of safety precautions.	5	4	3	2	1	0	
	• Participates in performance improvement and information management activities.	5	4	3	2	1	0	
	• Executes maintenance programs for the repair, preventive maintenance checks and services (PMCS), electrical safety testing and calibration/verification/certification (CVC) of medical materiel.	5	4	3	2	1	0	
	• Establish a master file of both operator and maintenance manuals in the maintenance activity for all medical equipment.	5	4	3	2	1	0	
	• Establishes a system for identifying defective equipment to alert potential users.	5	4	3	2	1	0	
	• Establishes a functional file system to ensure maintenance records are maintained.	5	4	3	2	1	0	
	• The organization maintains timely and informative communications with medical equipment operators or hand-receipt holders concerning maintenance services.	5	4	3	2	1	0	
	• Performs electrical safety testing after repairs or modifications to the equipment's electrical or electronic circuitry.	5	4	3	2	1	0	
	• Performs calibration after replacement of any circuit boards or when repairs or adjustments have been made to the electronic circuitry.	5	4	3	2	1	0	
	• Establishes cyclic (scheduled) maintenance service intervals consistent with the published manufacturer's literature.	5	4	3	2	1	0	
	• Records the completion of scheduled services using the generated monthly scheduled work order.	5	4	3	2	1	0	
	• Evaluates and performance test defibrillators semiannually using a defibrillator analyzer.	5	4	3	2	1	0	
	• meets the equipment manufacturer's serviceability and performance standards to be suitable for patient care and use.	5	4	3	2	1	0	

	• Can repair defective scientific and nuclear medicine and radiotherapy equipment in their respective institution • Can repair other type of defective medical equipments. • Have other specialized teams apart from medical Engineers. E .g. Mechanical Engineers • Provide on-the-job training at national and International level.	5 5 5 5	4 4 4 4	3 3 3 3	2 2 2 2	1 1 1 1	0 0 0 0	

- Verify how frequently does the organization repair defective equipment? Give examples for specific equipment.
  ……
  ……
- Describe the contracted services, indicating the type of equipment, services and conditions.....
  .....

- Verify whether the organization has the preventive maintenance manuals (protocols in detail) or they fully rely on in-house
  service?.....
  .....

- Describe the type of equipment that the organization repairs?
  ……
  ……

- Verify the number of the breakdown after 2880 hours……
  ……

- Verify the frequency of the breakdown on medical equipments after 2880 hours……
  ……

(vii)	**DECOMMISSIONING AND DISPOSAL.** **Verify whether;** • For any serviced toxic equipment infection control is consulted and that cleaning schedules/ procedures are agreed and are in place. • The hospital able to increase or decrease its use of the facility if its requirements change. • The hospital Management influences the disposition of the facilities. • The organization has appropriate facilities and program for liquidation.	5 5 5 5	4 4 4 4	3 3 3 3	2 2 2 2	1 1 1 1	0 0 0 0	

Interest of Research

- Does your organization require the result from the questionnaire?.....
  .....
  .....
- Explain the benefits your organization may achieve after the survey activity……
  ……
  ……
- In regards to the above questionnaire I wish to make request for your approval to carry out survey in your institution.

  Tick

  Yes ☐

  No ☐

APPENDIX B

B.1 PROGRAMME DEVELOPMENT

B.1.1 Introduction

The computer program majored in four categories of medical equipment namely;

- Laboratory equipment; Blood gas and Bacterial incubators
- Diagnostic equipment; Diagnostic X-ray machine, Ultra-sound machine
- Therapeutic equipment; Dialysis Machines, Short-wave machine
- Hospital equipment; Oxygen plant, Autoclaves

In each set of categories, two equipment were choosen and the fault coded in series aganist the equipment;

- Laboratory equipment; Bloodgas analyzer coded: blood-gas:50001-50010 ; Bacterial incubators coded: incubator:10010-10013
- Diagnostic equipment; Diagnostic X-ray machine coded: X-ray:40001-40010 ; Ultra-sound machine coded: ultrasound:70001-70011
- Therapeutic equipment; Dialysis Machines coded: dialysis:3000-3100 ; Short-wave machine coded: SWD:02001-02009
- Hospital equipment; Oxygen plant coded: oxygenplant:60001-60007 ; Autoclaves coded: autoclave:03001-03022

  The programme fault coding and the programme development are shown below;

TROUBLE SHOOTING OF MEDICAL EQUIPMENT.

CODE	PROBLEMS
SWD: 02001	Mains supply fuse blows with unit switch off
SWD: 02002	Mains input circuit breaker activated as it is switched ON
SWD: 02003	Circuit breaker activated when tuning to maximum
SWD: 02004	Control circuit fuse blows up
SWD: 02005	Unit switched ON meter reads detuned condition only
SWD: 02006	No-tuning
SWD: 02007	Unit switched on and under detuned conditions meter reads about half normal reading
SWD: 02008	Output meter readings low together with the available output
SWD: 02009	Buzzer sounds when timer is operated
autoclave: 03001	Power indicator fails
autoclave: 03002	Chamber temperature increament fails
autoclave: 03003	Sterilization timers will not be active
autoclave: 03004	Steam escapes throug the lid gasket
autoclave: 03005	Completion buzzers will not sound
autoclave: 03006	Display shows dr when cycle start button pushed
autoclave: 03007	Safety breaker is cut off
autoclave: 03008	Electric shock occurs when touched
autoclave: 03009	Temperature rises however pressure does not rise
autoclave: 03010	Cannot open door

autoclave: 03011	**Chamber will not fill with water**
autoclave: 03012	**Display shows Err3**
autoclave: 03013	**Display shows test door**
autoclave: 03014	**Safety valve operates below 136'C**
autoclave: 03015	**Safety valve leaks**
autoclave: 03016	**Err3 displayed before sterilizing temp reached**
autoclave: 03017	**Err4 displayed after sterilizing temp reached**
autoclave: 03018	**Err5 displayed**
autoclave: 03019	**Temp differs from measured value**
autoclave: 03020	**No discharge at end of cycle**
autoclave: 03021	**Cycle time excessive compared with usual value**
autoclave: 03022	**Excessive noise from reservoir during discharge**
blood-gas: 50001	**Power indicator fails**
blood-gas: 50002	**Inaccurate reading**
blood-gas: 50003	**Inability to perform two point calibration**
blood-gas: 50004	**Offscale readings**
blood-gas: 50005	**Drift**
blood-gas: 50006	**Slow reponse**
blood-gas: 50007	**Daily ppm**
blood-gas: 50008	**Weekly ppm**
blood-gas: 50009	**Monthly ppm**
blood-gas: 50010	**Six-monthy ppm**
x-ray:40001	**No unit movements**

x-ray:40002	**Collimator cannot be operated from console**
x-ray:40003	**Tomography cannot be selected**
x-ray:40004	**Tilt drive idle**
x-ray:40005	**Column drive idle**
x-ray:40006	**Controlled and no movement**
x-ray:40007	**Oblique radiation angle**
x-ray:40008	**Uneven movement of column and spotfilm device drive**
x-ray:40009	**Incorrect collimation**
x-ray:40010	**X-ray exposure switch is released in the middle of exposure**
ultrasound: 70001	**No-output**
ultrasound: 70002	**Low meter reading**
ultrasound: 70003	**High meter reading**
ultrasound: 70004	**Fuse blows continuously**
ultrasound: 70005	**Large harmonic content output**
ultrasound: 70006	**Low acoustic output**
ultrasound: 70007	**Poor linearity**
ultrasound: 70008	**Flickering**
ultrasound: 70009	**Excess noise**
ultrasound: 70010	**Gross image deterioration**
ultrasound: 70011	**Change in image quality**
oxygenplant: 60001	**Oxygen generator does not cycle**
oxygenplant: 60002	**Oxygen generator turns on, green power indicator fails**
oxygenplant: 60003	**Oxygen generator does not turn on and power light is on (green)**

oxygenplant: 60004 **Oxygen generator turns ON and cycles, amber light does not work**

oxygenplant: 60005 **Oxygen generator does not turn ON. Power light is on (green), Auto manual switch in auto position amber light off.**

oxygenplant: 60006 **Oxygen generator runs continuously, oxygen supply pressure 58psig or higher**

oxygenplant: 60007 **Oxygen generator runs continuously, receiver pressure is less than 40psig**

oxygenplant: 60008 **Low purity oxygen**

oxygenplant: 60009 **Low purity oxygen; solenoid valve not functioning**

oxygenplant: 60010 **Low purity oxygen; valve remains open**

oxygenplant: 60011 **Valve chattering loudly**

oxygenplant: 60012 **Air regulator leaks out**

oxygenplant: 60013 **Filter drain valve not energized**

oxygenplant: 60014 **Filter drain valve remains energized**

incubator: 10001 **No output**

incubator: 10002 **Temperature inside too high**

incubator: 10003 **Temperature inside too low**

incubator: 10004 **Severe overflow of water evaporation tray**

incubator: 10005 **Drawers not sliding**

incubator: 10006 **Display not responding**

incubator: 10007 **Door alarm sounding**

incubator: 10008 **Agitation alarm sounding when unit is agitating**

incubator: 10009 **Alarm sounding sporadically**

incubator: 10010 Condenser temperature alarm sounding

incubator: 10011 Power failure alarm sounding

incubator: 10012 Incorrect temperature display

incubator: 10013 Audible alarm not activating

```
#include <iostream.h>
#include <cstring>
int main ()
{
        char*dictionary[][2]=
        {
                "blood-gas-analyzer","Labarotory Equipment",
                "bacterial-incubator","Labarotory Equipment",
                "x-ray-machine","Diagnostic Equipment",
                "ultrasound-machine","Diagnostic Equipment",
                "dialysis-machine","Theraupetic Machine",
                "shortwave-machine","Theraupetic Machine",
                "oxygen-plant","Hospital Equipment",
                "autoclave-machine","Hospital Equipment",
                "",""
};
char machine[200];
int i;
cout<<"Enter machine name<<\t";
cin>>machine;
for(i=0;*dictionary[i][0];i++)
{
        if(!strcmp(dictionary[i][0],machine))
        {
                cout<<dictionary[i][1]<<"\n\n";
```

```
                break;
        }
}
if(!*dictionary[i][0])
{
cout<<machine<<"\tnot Found\n\n";
return *dictionary[i][0];
}
{
char*dictionary[][2]=
{
        "SWD:02001","faulty cable connection at plug, damaged mains cable, fault in mains
        filter box",
        "SWD:02002","fault on the transformer or associated components, wrong connections of
        valve filament circuit, fault mains on/off switched",
        "SWD:02003","Rectifier diode module fails on load, faulty condition in oscillator valve
        or valves, wrong connection between grid and filament",
        "SWD:02004","The problem can only be connected with following components:patient
        release relay and it associated wiring, warning buzzer and its associted rectifier and
        condenser",
        "SWD:02005","wrong electrodes and poor spacing, failure of coupling device associated
        with output control",
        "SWD:02006","improper connection to moving coupling coil",
        "SWD:02007","Failure of rectifier module, open circuit on one half of capacitor bank",
        "SWD:02008","Failure of one oscillator valve",
        "SWD:02009","Damaged patient release switch",
        "autoclave:03001","power failure, incomplete plugging of the power cord, the safety
        breaker is cut off, power indicator defective, main fuse blown",
```

"autoclave:03002","Disconnection of heater wiring or mulfunction of electric circuit, the steam trap defective, air leakage from the safety valve, air leakage from the exhaust valve, the pressure gauge defective",

"autoclave:03003","mulfunction of electric circuit, the steam trap defective, air leakage from the safety valve, air leakage from the exhaust valve, the pressure gauge defective",

"autoclave:03004","incorrect settlementof the lid, incomplete tightening of the lid, soiled lid gasket, scratched or cracked lid gasket, incorrect placementof the lid gasket",

"autoclave:03005","Electrical circuit defective,the buzzer defective",

"autoclave:03006","Blocking of drain pipings",

"autoclave:03007","heater is damaged, malfuction of the safety breaker or electric circuit",

"autoclave:03008","The circumference of the instrument is wet with water, the power plug and cord are damaged, grounding is not effective, heater is damaged by empty heating",

"autoclave:03009","temperature display faulty, pressure gauge faulty, controller or triac faulty",

"autoclave:03010","pressure door lock jammed, pressure in chamber, chamber with vacuum, solenoid door lock inoperative when unit power is switched on",

"autoclave:03011","Faulty float switch, No water in reservoir",

"autoclave:03012","water fill valve or associted pipes blocked, air valve stuck in position, air lock in water feed pipe from reservoir",

"autoclave:03013","door interlock microswitched jammed in closed position, fault switch",

"autoclave:03014","air valve sticking, safety valve fault, recalibration needed, temp sensor fault controller",

"autoclave:03015","Dirt on valve seat, check pressure gauge display to see if sterilizing temperature is set to high, air valve sticking",

"autoclave:03016","No water in chamber, air valve sticking, water fill valve is leaking, discharge valve leaking, chamber water level sensor fault",

"autoclave:03017","steam leak, water fill valve leaking, discharge valve leaking, temperature sensor fault",

"autoclave:03018","Heater open circuit, manual reset thermostat operated or open circuit, solid state relay failed, controller faulty, chamber water level sensor short circuit",

"autoclave:03019","Recalibration required, air valve partially blocked, faulty controller, voltage regulator not properly mounted or loose",

"autoclave:03020","Discharge valve faulty, wiring faulty, blockage in discharged line, faulty controller, filter blocked",

"autoclave:03021","Low mains voltage, autoclave overloaded, slow discharge at end of cycle",

"autoclave:03022","positioning of discharge line in reservoir incorrect"

"blood-gas:50001","power failure, incomplete plugging of the power cord, the safety breaker is cut off, power indicator defective",

"blood-gas:50002","pH electrode aged or contaminated buffers",

"blood-gas:50003","pH electrode aged or contaminated buffers",

"blood-gas:50004","unit not properly grounded, electrodes not plugged firmly, refrence electrode has been filled with the wrong solution",

"blood-gas:50005","Electrodes in unbuffered solution such as distilled water respond more slowly, wrong type of electrode is used",

"blood-gas:50006","Electrodes in unbuffered solution such as distilled water respond more slowly, wrong type of electrode is used",

"blood-gas:50007","cleaning of blood residues from waste lines, waste containers entrance ports and valves, calibration checks",

"blood-gas:50008","change of electrode membranes, change of calibration gases, checking of gas line tubings for any sign of damage, change of tubings if damaged"

"blood-gas:50009","change of electrode membranes, inspection of valves, electronic performance tests as per manufacturing manual",

"blood-gas:50010","consult the contractor",

"x-ray:40001","CPU board defective, console interface board defective, fibre optic cable defective",

"x-ray:40002","x-ray tube centered switch not properly adjusted",

"x-ray:40003","column not centered, compression not in park position, SID not set to 115cm",

"x-ray:40004","faulty potentiometer, CPU board failed",

"x-ray:40005","faulty potentiometer, CPU board failed",

"x-ray:40006","faulty motor, CPU board failed, safety limit switch actuated",

"x-ray:40007","faulty potentiometer, motor failed, tachogenerator failed",

"x-ray:40008","potentiometer defective, centered position of column and spotfilm device changed",

"x-ray:40009","the collimator may be loose, the tube housing may have rotated",

"x-ray:40010","Release error by pushing the reset switch on the remote box",

"ultrasound:70001","no main supply, blown up fuse, tuning oscillator faulity",

"ultrasound:70002","faulty rectifying diodes, low supply volts",

"ultrasound:70003","wrong oscillation frequency, output coupling network faulty, transformer secondary winding faulty",

"ultrasound:70004","rectifying diodes faulty, output coupling network faulty, transformer secondary winding faulty",

"ultrasound:70005","oscillation frequency high at 2Mhz, faulty transducer",

"ultrasound:70006","faulty transducer or connections, oscillator frequency incorrect",

"ultrasound:70007","transducer efficiency low, oscillator incorrect, oscillator frequency pulling a part",

"ultrasound:70008","break in one or more of the cable conductors, mishandiling of the cable",

"ultrasound:70009","the motor and bearing fails",

"ultrasound:70010","prences of air bubbles, faulty transducer, transducer may not have been properly adjusted ",

"ultrasound:70011","preamplifier mulfunction, faulty monitor or preprocessing unit",

"oxygenplant:60001","unit not plugged in, Blown fuse, Blown breaker",

"oxygenplant:60002","Light burned out, defective wire",

"oxygenplant:60003","power switch off, defective power switch, defective power wire to circuit",

"oxygenplant:60004","light burned out, defective wire, defective circuit board",

"oxygenplant:60005","power switch is off, defective power switch, defective power wire to circuit board, pressure switch adjusted improperly, pressure switch defective, defective circuit board",

"oxygenplant:60006","pressure switch not adjusted properly, defective pressure switch, defective wire going to pressure switch, defective switch, defective circuit board",

"oxygenplant:60007","Air supply pressure too low, cycle pressure too low, oxygen usage is greater than capacity of generator",

"oxygenplant:60008","iniatial startup, leaky check valve, long shut-down, momentary power loss, low suppy air, low feed air, valves not cycling properly, improperly wired or defective circuit board, valve diaphragm torn",

"oxygenplant:60009","defective coil, defective wire to valve, defective circuit board, defective valve",

"oxygenplant:60010","valve internal parts worn, valve remains energized",

"oxygenplant:60011","low voltage, low voltage circuit board output, dirty valve, worn valve core, defective EMI filter",

"oxygenplant:60012","main regulator valve assembly is struck, main valve assemble seat no good",

"oxygenplant:60013","valve plugged, defective push button, defective wire to valve",

"oxygenplant:60014","manual push button stuck, circuit board defective",

"incubator:10001","Circuit breaker on the Incubator is open, Power switch is not on or faulty. Faulty outlet connection. Faulty power cord. Faulty Temperature controller / controller settings. The compressor, compressor starting relay or capacitor is defective",

"incubator:10002","Temperature set point may need to be adjusted. The refrigeration condenser is dirty. There is inadequate circulation inside the incubator chamber. Condenser fan motor is not running.The ambient air temperature in the area of the incubator is too high. Temperature Probe may be defective or not in the proper location. The temperature controller is faulty or has improper settings.",

```
"incubator:10003","The temperature controller is faulty or has improper settings.
Temperature Probe may be defective or not in the proper location. Interior heater or
thermostat may be defective.",

"incubator:10004","The heater in the evaporation tray is faulty.",

"incubator:10005","Drawer slide rail needs to be lubricated. Debris is in drawer slide.
Drawers are not level or are misaligned. Faulty drawer slide",

"incubator:10006","Digital electronics are locked due to power interruption.",

"incubator:10007","Door alarm time out is set at 0 minutes. The doors do not close
completely. Faulty door switch. Door switch bracket is not properly aligned",

"incubator:10008","Agitation motion sensors are faulty or not connected.",

"incubator:10009","Temperature set point may need to be adjusted. Temperature probe
may be in the wrong location, or defective. Temperature in the unit may be unstable.",

"incubator:10010","Condenser alarm set point is too low. Compressor is overheating.
Condenser fan motor is not running. Condenser temperature probe is faulty",

"incubator:10011","Power switch is not ON or is faulty. Circuit breaker is open or faulty.
Faulty outlet connection. Cause: Faulty power cord.",

"incubator:10012","Alarm monitor needs to be calibrated, Digital electronics are locked
due to power interruption, Temperature probe is disconnected from circuit board, Cause,
Temperature Probe may be defective",

"incubator:10013","Alarm Key switch is in the OFF position, Alarm set points incorrect,
Faulty alarm",

"","""
};

char fault[1000];

int i;

cout<<"Enter the type of fault<<\t";

cin>>fault;

for(i=0;*dictionary[i][0];i++)

{
```

```
        if(!strcmp(dictionary[i][0],fault))
        {
                cout<<dictionary[i][1]<<"\n\n";
                break;
        }
}
if(!*dictionary[i][0])
cout<<fault<<"\tnot Found\n\n";


{
char*dictionary[][2]=
{
"incubator:PC100h","equipment under warrant: supplier technician to repair",
"incubator:PC900h","equipment under warrant: supplier technician to repair",
"incubator:PC2200h","equipment under warrant: supplier technician to repair",
"incubator:PC3200h","equipment under warrant: supplier technician to repair",
"x-ray:Panoura","equipment under warrant: supplier technician to repair",
"x-ray:Type B","equipment under warrant: supplier technician to repair",
"dialysis:fresenius-2008k","equipment under warrant: Technician from supplier's center to repair",
 "","",
};
char serialNo[200];
int i;
cout<<"Enter serial number to find whether the equipment is under warrant\n";
```

```
 else if (equipment>=3&&equipment<10)
 {
  cout<<"The in-house technician to repair the equipment"<<endl<<endl;
 }
 else
 {
        cout<<"Equipment obsolute: Replace the equipment";
 }
 cin.get();
}
return 0;
}
}
}
```

APPENDIX C

C.1 PROGRAMME PRINTOUT

Enter machine name and serial number: analyzer: 2200

Equipment Name:Blood gas Analyzer. Category: Labarotory Equipment. Manufacturer: Bayer. Model No: 248. Supplier Company: Chemoquip Engineering Ltd. Department: Labarotory. Last Serviced Date: 9th June 2011. Next Planned Preventive Maintenance Date: 9th September 2011.

Enter the type of fault: blood-gas:50004

Unit not properly grounded.
Electrodes not plugged firmly.
Refrence electrode has been filled with the wrong solution.

Enter serial number to find whether the equipment is under warrant: 2200

Equipment serial no 2200 not warranted:
In-house technician to repair the equipment

Enter the duration (in years) since the equipment was supplied to the hospital: 4 year

The in-house technician to repair the equipment.

END OF PROGRAM

Press any key to continue