Sudan University of Science and Technology

College of Graduate Studies

Assessment of medical engineering workshops in Khartoum state's hospitals

تقييم لورش الهندسة الطبية في مستشفيات ولاية الخرطوم

A Thesis Submitted in Partial Fulfilment of the Requirements for the Degree of Master in biomedical Engineering

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قال الله تعالى:

﴿ وَقُل رَّبِّ زِدْنِي عِلْمًا ﴾

طه (114)

Dedication

I would like to dedicate this piece of work to my parents and who supported me in every step of my life. I dedicate every success to them and to my teachers and to all those who participate to complete this work.

Acknowledgement

Before I begin my thanks, I must first pay the highest to the creator of mankind, ALLAH.

I would like to express my special thanks to my supervisor Dr.Fragoon Ahmed; I am very grateful for his guidance and show of interest in my work. Also many thanks to all those who participate to complete this work.

Abstract:

To get the most out of medical equipment we need to actively manage them, ensuring that they are used efficiently and optimally, and this will lead to improvements in the quality and quantity of healthcare delivered, without an increase in costs. So, we are in need for applying an ideal design of clinical workshops depending on hospitals' capacity. The project aims to assess the status quo of clinical engineering workshops in Khartoum state's hospitals in terms of the constructions and their performance and to how much they match the standard workshops. Firstly, we design a controlled structured visual inspection sheet. Then we delivered this sheet to clinical engineers at hospitals under study. Secondly, we measured the dimensions of current workshops, counted the functional items inside the workshops and draw them using ArchiCAD to compare between the actual workshop and the ideal one; thus to find the gap between them. The results that obtained reflect the actual status of medical workshops in Khartoum state for the hospitals under the study. In all hospitals under the study the workshops are not typical workshops for clinical engineering department depending on operating capacity of these hospitals in beds. Furthermore there is 20 percent of these hospitals have no workshops at all and 70 percent of existing workshops lack of many requirements of Ideal workshops in terms of typical dimensions, internal divisions, contents and not taking into account the comfortable area of work within the workshop without overlapping of workers during the performance of their duties. Only twenty two of thirty samples have workshops, so we have a result of these twenty two samples.

المستخلص:

للحصول على أقصى إستفاده من الأجهزه الطبيه, نحتاج إلى إدارتها بفعاليه, و ضمان إستخدامها بكفاءه و على النحو الأمثل؛مما سيؤديإلى تحسين جودة و مقدار الرعايه الصحيه المقدمه و ذلك دون زيادة التكاليف. لذلك نحن بحاجه إلى تطبيق تصميم مثالي لورش الهندسة الطبيه وفقا للسعة التشغيليه للمستشفيات. يهدف البحث إلى محاولة تقييم الوضع الراهن للورش الطبيه في بعض مستشفيات ولاية الخرطوم و ذلك من ناحية مبانى الورش بأقسامها المختلفه وفاعلية الأداء لهذه الورش , و مدى مطابقتها للورش المثاليه. تمم تصميم إستبيان بعد تحكيمها و من ثم تم تسليم هذا الإستبيان إلى المهندسين الطبيين في المستشفيات قيد الدراسه.و أيضا تم قياس أبعاد الورش الحاليه و إحصاء الأجزاء و المكونات الفعاله داخل الورشه الحاليه و تم رسمها بإستخدام ال(ArchiCAD) و ذلك للمقارنة بين الورشه الفعليه و المثاليه منه وذلك لمعرفة الفرق بينهما و ما نحتاجه للوصول للمثاليه.النتائج المتحصل عليها عكست الوضع الحقيقي لهذه الورش تحت الدراسه والتي كانت ثلاثون عينه و كانت المستشفيات التي تحتوي على ورش هندسية طبية عباره عن إثنين و عشرين عينه فقط و التي تمثل 70% من المستشفيات تحت الدراسه. وهذه الورش الموجوده جميعها غير مثاليه بالنسبه للمندسين الطبيين و ذلك إعتمادا" على السعة التشغيليه لهذه المستشفيات و الأقسام الداخليه و معينات العمل والمساحه التشغيليه الداخليه للورشه من غير حدوت تقاطع للعاملين داخل الورشه أثناء تأدية المهام المختلفه. علاوة على ذلك , يوجد 20 % من المستشيفات تحت الدراسه لا تحتوي على ورشه طبيه في الأصل.

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Abbreviations

WHO	World Health Organization
HTA	Health Technology Assessment
CT	computed tomography
US	United States
GDP	gross domestic product
TA	technology assessment
HTM	healthcare technology management
ECG	electrocardiograph
PPM	planned preventive maintenance
HTMS	healthcare technology management service
SPSS	Statistical package for the social sciences
Eng.	Engineer
BMEs	Biomedical engineers
BMWS	Biomedical work shop

Chapter One
Introduction

1.1 Overview:

All health service providers want to get the most out of their investments. To enable them to do so, they need to actively manage health service assets, ensuring that they are used efficiently and optimally. All management takes place in the context of the health system's policies and finances. If these are favorable, the management of health service assets can be effective and efficient, and this will lead to improvements in the quality and quantity of healthcare delivered, without an increase in costs.

However the World Health Organization (WHO) uses the broader term 'health technology', which it defines as including: 'devices, drugs, medical and surgical procedures – and the knowledge associated with these – used in the prevention, diagnosis and treatment of disease as well as in rehabilitation, and the organizational and supportive systems within which care is provided.'

Here, the phrase 'healthcare technology' is only used to refer to the various equipment and technologies found within health facilities (the physical pieces of hardware in the WHO definition that need to be maintained). Drugs and pharmaceuticals are usually covered by separate policy.

The health service's most valuable assets which must be managed are its human resources, physical assets, and other resources such as supplies. Physical assets such as facilities and healthcare technology are the greatest capital expenditure in any health sector. Thus it makes financial sense to manage these valuable resources, and to ensure that healthcare technology:

- is selected appropriately
- is used correctly and to maximum capacity
- lasts as long as possible.

Such effective and appropriate management of healthcare technology will contribute to improved efficiency within the health sector. This will result in improved and increased health outcomes, and a more sustainable health service. [1]

1.2 Problem statement:

There is no ideal designs of workshops are applied in Khartoum's hospitals that accommodate the workers and the tools in Khartoum. And this leads to weak the quality performance of equipment in terms of results' reliability. Thus, affect doctors' decisions.

1.3 Objectives:

1.3.1 General objective:

- Assessment of current situation of workshops in Khartoum state's hospitals.

1.3.2 Specific objective:

- To find the gap between the current work shop and an ideal design of workshops based on international standard.
- Draw the actual workshops using ArchiCAD program to compare between them and the standard ones.
- To manage the workshops at hospitals in a way, that guarantee the continuity of perfect services that provide in medical field through a good handling of the medical equipment.

1.4 Research layout:

This research includes six chapters: chapter one is an introduction that contains the general review, problem statement and the objectives of research. Chapter two contains the literature review. The theoretical background is described in chapter three. Chapter four describes the methodology of data collection**.**

Chapter five shows the actual workshops Vs the typical ones. Ultimately, the recommendation and conclusion are discussed in chapter six.

Chapter two

Literature Review

2.1 Introduction:

In the last few years, breakthroughs in the health-care sector have yielded many advances that improved medical delivery, patient access, and health outcomes. Technological innovations have produced remarkable results. New procedures, equipment, and processes, including new medical and surgical procedures (e.g., angioplasty and joint replacements), drugs (e.g., biologic agents), medical devices [e.g., computed tomography (CT) scanners and implantable defibrillators], and new support systems (e.g., electronic medical records and telemedicine) by which medical care is now delivered, have heralded a new era for health-care provision. [3]

Biomedical engineering and its resulting technological innovations have played a very important role in these developments. It is generally defined as the use of principles and techniques of engineering to solve problems in biology and medicine [5]. As such, biomedical engineering provides tools and the means to improve health-care delivery in both diagnosis and treatment of diseases. These tools include instrumentation, medical imaging, and medical devices such as cardiac pacemakers, artificial limbs, artificial vision, devices for the hearing impaired, and dialysis instrumentation.

The term biomedical technology is usually meant to include engineering and various sciences such as biology, mechanical engineering, and materials science. The terms biotechnology and medical devices have blurred boundaries. There are many health-care products that are the result of various disciplines. The complexity of the health-care delivery system requires the use of multiple engineering and sciences to arrive at useful products and processes in the diagnosis and therapeutic aspects of treating patients. ‘‘Health (Biomedical) Technology’’ shows the categories of the biomedical technology universe. [3]

The particularly rapid development in health technologies has increased the health-care expenditures. In the last decade, the biomedical industry has been the fastest growing sector of the U.S. economy, and new medical technologies have been one of the drivers for the rise in health-care costs. Since 1970, in the United States, health-care spending has grown at an average annual rate of 9.8%, about 2.5% points faster than the economy, as measured by the nominal gross domestic product (GDP). Annual spending on health care increased from US$75 billion in 1970 to US$2.2 trillion in 2007, and it is estimated to reach US$4.3 trillion in 2018. As a share of the economy, health care has more than doubled over the past 35 years, rising from 7.2% of GDP in 1970 to 16.2% of GDP in 2007, and it is projected to be 20.3% of GDP in 2018. Health-care spending per capita increased from US$356 in 1970 to US$7,421 in 2007, and it is projected to rise to US$13,100 in 2018[6].

The increasing level of health-care costs—partly driven by medical technologies—could lead to economic unsustainability of the health-care delivery system and therefore to the rationing of care and cuts in expenditures and investments in the system. In this forthcoming scenario, there will be growing pressures to develop and adopt medical technologies that are more cost effective. The focus will be increasingly on the appropriate use of technologies in clinical practice and in the administration of health-care delivery organizations [7] .Therefore, the role of screening and evaluation of medical technologies will become a crucial component of the decision process to acquire, implement, and adopt these technologies. HTA will become the mechanism by which the resources will be allocated by health-care decision makers to future medical technologies [8].

Areej A.and Manal M., Design of Medical Equipment calibration, Maintenance and Consultation Center (2014). In this project, the state of preventive maintenance and calibration of medical equipment’s in Khartoum hospitals are studied and according to it, a medical equipment center for calibration,

maintenance and consultation which is appropriate with the requirements and the capabilities of Khartoum hospitals is designed. [28]

2.2 What is Health Technology Assessment (HTA):

Health technology assessment (HTA) provides an assessment and prioritizing of new technologies against existing health care interventions and other government funding priorities. [4]

Health technology is referred to any intervention that may be used for safe and cost effective prevention, diagnosis, treatment and rehabilitation of illness and disease. This includes the pharmaceuticals, devices, procedures and organizational systems used in health care. [4]

There are many definitions of HTA and here are some of them:

Health technology assessment (HTA) is an evaluation tool that applies systematic methods of inquiry to the generation and use of health technologies and new products. [3]

The Institute of Medicine [9] offered the following definition of HTA: to denote any process of examining and reporting properties of a medical technology used in health care, such as safety, efficacy, feasibility, and indications for use, cost, and cost effectiveness, as well as social, economic, and ethical consequences, whether intended or unintended. [3]

Health technology assessment (HTA) is the systematic evaluation properties, effect, and/or impacts of health technology. Its main purpose is to inform technology related policy-making in health care, and thus improve the uptake of cost-effective new technologies and prevent the uptake of technologies that are of doubtful value for the health system. HTA examines the effectiveness, safety, economic, social and ethical implications of incremental value, diffusion and

use of a health technology in health care. The main issues considered as part of a HTA are: Dose the technology work? What is the benefit to the individual? At what cost? How does it compare to the alternatives? HAT links research and decision making and inform policy, funding and clinical decisions. [4]

HTA pertains to the systematic evaluation of the properties and effects of health technologies (whether drugs, medical devices, surgical procedures or organizational aspects of health systems [21]), addressing their direct and intended effects, as well as their indirect and unintended consequences with the aim of informing decision making [22].

In general, HTA is a policy analysis process including two components; firstly, an assessment of all available evidence relevant to the policy questions at hand and secondly, an appraisal of the findings from the evidence to reach a decision [23]. The prior of these components (i.e. assessment) is conventionally a scientific, robust process [23].

2.3 Needs and Origins of (HTA):

In recent years, there has been an increasing demand for a better understanding of the processes by which medical technologies are marketed, regulated, paid for, and utilized [9],[10]. This demand comes from every constituent of health-care delivery system. [3]

Makers of medical devices, clinicians, hospital administrators, payers, and regulators are all supporting the effort to gather more information about the performance of medical technologies. This has led to the generation of HTA field of research and adoption by health-care organizations. [3]

HTA had emerged from technology assessment (TA) as a discipline that aims to establish clinical, economic, and managerial/ behavioral methods to assess the

alternatives offered by medical technologies for new diagnostics and therapeutic opportunities [7].

Coates and Jarratt [11] defined (TA) as a category of policy studies, aimed at supplying policy makers with the information they need to make good decisions. Banta and Luce [12] added the notion of providing decision makers with policy alternatives. [3]

2.4 The Role of (HTA) in Health-Care Delivery:

When TA is applied in health-care policy and management, the definition of this evaluative tool becomes more specific to medicine. [3]

In addition to providing inputs to health policy makers, the role of HTA is to facilitate the appropriate introduction and use of new health technologies[13],[14],[3].

HTA contributes to the encouragement and sustainability of medical innovations, because it provides evidence of the generation of positive outcomes from these innovations and the justification for the investments made in medical technologies research and development.

HTA is a structural analysis of health technology and is predicated on the functions of knowledge generation and knowledge. These functions create a platform upon which health policy makers can make judgments based on evidence.

The knowledge-generation functions of HTA may include the following :

- Identifying evidence or lack of evidence on the benefits and costs of health-care interventions.
- Synthesizing health research findings about the effectiveness of different health interventions.

- Evaluating the economic implications and analyzing cost and cost effectiveness.
- Appraising social and ethical implications of the diffusion and use of health technologies as well as their organizational implications.

The knowledge utilization functions of HTA may include the following :

- Dissemination of information to policy makers, providers, and patients.
- Facilitating practice change through various policy instruments.
- Researching service, organization, and development structures, and their effects on the behavior of providers.
- Tracking, monitoring, and policing of knowledge use.

Health technologies have to be assessed from the developmental stage to the final stage, and they are different depending on the technology as follows :

- **New**: sometimes in a conceptual stage or in the earliest stages of development, more often over the clinical investigation but not yet in a routine use.
- **Emerging**: in the applied research stage, about the time of initial clinical investigation, i.e., experimental, like in the case of robot-assisted surgery.
- **Consolidated**: already diffused into general use and considered by providers and patient like standard approaches.
- **Obsolete**: replaceable by another technology and/or nearly ineffective or harmful.

Often, these stages are not clearly delineated. Many technologies undergo multiple incremental innovations after their initial acceptance into general practice [8],[15],[3]. A technology that was once considered obsolete may return to consolidated use for a better defined or entirely different clinical purpose. [3]

2.5 The Biomedical Product Development Process:

The biomedical product development process is shown in the next Figure 2-1:

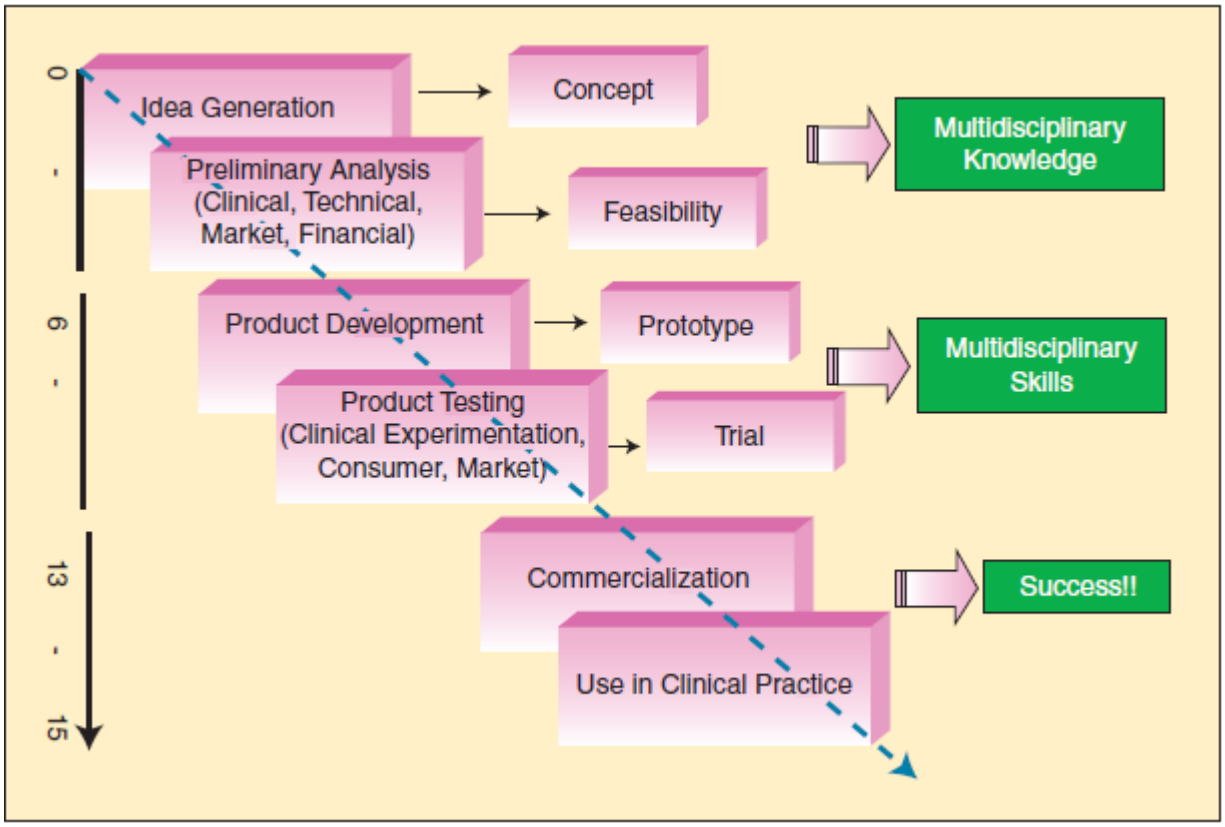


Figure 2-1: Biomedical product development process.

This process, which generates biomedical innovations, is more complex than the innovation continuum in other industries [24].

The main reasons for the complexity of this process include the presence of multiple interested parties, the interface of several scientific disciplines, the need for coordination between technology and clinical use, and the strong ethical implications of innovations.

Every stage in this process is subject to a different combination of these factors and to the pressures from different constituencies and stakeholders. The regulatory involvement starts very early in the life of the biomedical process.

This creates an even greater need for continuous analysis and data generation by means of evaluation and audits.

In this process, there is an accentuated need for feedback and exchanges between the various stages. Results from clinical trials, for example, are critical to previous stages, before the process continues toward commercialization and ultimate clinical use. This interdependency among stages is much stronger than in other industries—such as chemicals or consumer products— because of the sensitivity of each stage to external factors of regulatory, social, ethical, and medical constraints. [3]

2.6 HTA in Biomedical Product Innovation:

HTA in the biomedical innovation process has a dual role:

First, it generates evaluations for each phase of the process as well as comprehensive assessment of the product development continuum. By doing so, HTA creates content for the continuing feedback given to managers throughout the process. Such content is the knowledge the managers need to make reasoned decisions on whether to continue the development process and what needs to be corrected at each phase [3].

Second, HTA serves as a gatekeeper for the new product development process. The knowledge produced by HTA provides inputs at each phase for decisions on the success or failure of each phase of the process. As shown in Figure, HTA generates an assessment of a very complex and multidisciplinary flow of phases. The road from concept to prototype and then to trial and commercialization includes a variety of disciplines and skills so that the degrees of specialization and disciplinary zeal tend to obfuscate a proper internal evaluation. The need arises for an effective assessment by an external perspective [13], [16],[17]-[3].

The long-standing experience and scholarship in the evaluation of new product development in a variety of industrial settings allow for much desired lessons for the biomedical context of new product development. The flow of phases from idea generation to commercialization and utilization has been extensively studied [18], [19].

The differences between other sectors and the biomedical industry are in the added complexity of the process and its scientific content as well as in the downstream applications in medical practice. This latter distinction generates a special case in the utilization of the new product because of the highly regulated aspect of the industry and the Web of interfaces and interdependencies of each new product with existing frameworks, products, and systems in clinical use [25], [7], [10], [20],[3].

The implementation of HTA within the biomedical sector greatly contributes to the sound management of these organizations. Executive decisions can be consistently based on hard data and cogent analytical schemes. Unlike other industrial models for the assessment of new technologies, HTA provides the much-needed link between biomedical processes and health-care delivery.

To sum up, HTA is an essential tool for the support of decision makers at the levels of health policy strategy and operations. For the biomedical sector, HTA offers a unique instrument that allows for an evaluation of process and outcomes, leading to improved effectiveness of the biomedical new product development process and to better positioning and competitiveness of biomedical organizations. [3]

HTA, strengthened by its multidisciplinary and the interdisciplinary nature has emerged as an important tool to help policy-makers decide on technologies that need to be funded and that may not be funded.

Chapter three

Theoretical Background

3.1 Introduction:

The provision of equitable, quality and efficient healthcare requires an extraordinary array of properly balanced and managed resource inputs. Physical resources such as fixed assets and consumables, often described as healthcare technology, are among the principal types of those inputs. Technology is the platform on which the delivery of healthcare rests, and the basis for provision of all health interventions. Technology generation, acquisition and utilization require massive investment, and related decisions must be made carefully to ensure the best match between the supply of technology and health system needs, the appropriate balance between capital and recurrent costs, and the capacity to manage technology throughout its life.

Healthcare technology has become an increasingly visible policy issue, and healthcare technology management (HTM) strategies have repeatedly come under the spotlight in recent years. While the need for improved HTM practice has long been recognized and addressed at numerous international forums, health facilities in many countries are still burdened with many problems, including non-functioning medical equipment as a result of factors such as inadequate planning, inappropriate procurement, poorly organized and managed healthcare technical services, and a shortage of skilled personnel. The situation is similar for other health system physical assets such as buildings, plant and machinery, furniture and fixtures, communication and information systems, catering and laundry equipment, waste disposal, and vehicles.

The mismanagement of physical assets impacts on the quality, efficiency and sustainability of health services at all levels, be it in a tertiary hospital setting with sophisticated life-support equipment, or at the primary healthcare level where simple equipment is needed for effective diagnosis and safe treatment of patients. What is vital – at all levels and at all times – is a critical mass of affordable, appropriate, and properly functioning equipment used and applied

correctly by competent personnel, with minimal risk to their patients and to themselves. Clear policy, technical guidance, and practical tools are needed for effective and efficient management of healthcare technology for it to impact on priority health problems and the health system's capacity to adequately respond to health needs and expectations. [1]

3.1.1 Healthcare Technology:

The World Health Organization (WHO) uses the broader term ‘health technology’, which it defines as including:

‘Devices, drugs, medical and surgical procedures – and the knowledge associated with these – used in the prevention, diagnosis and treatment of disease as well as in rehabilitation, and the organizational and supportive systems within which care is provided.’ [26]

However, the phrase ‘healthcare technology’ is used here only refers to the physical pieces of hardware in the WHO definition, that need to be maintained.

Indeed, healthcare technology management (HTM) involves the organization and coordination of all of the following activities, which ensure the successful management of physical pieces of hardware [1]:

- Gathering reliable information about your equipment.
- Planning your technology needs and allocating sufficient funds for them.
- Purchasing suitable models and installing them effectively.
- Providing sufficient resources for their use.
- Operating them effectively and safely.
- Maintaining and repairing the equipment.
- Decommissioning, disposing of, and replacing unsafe and obsolete items.
- Ensuring staff have the right skills to get the best use out of your equipment.

This will require you to have broad skills in the management of a number of areas, including:

- Technical problems
- Finances
- Purchasing procedures
- Stores supply and control
- Workshops
- Staff development.

However, you also need skills to manage the place of healthcare technology in the health system. Therefore, HTM means managing how healthcare technology should interact and balance with your:

- medical and surgical procedures
- support services
- consumable supplies, and
- facilities

So that the complex whole enables you to provide the health services required.

Thus HTM is a field that requires the involvement of staff from many disciplines

– technical, clinical, financial, administrative, etc. It is not just the job of managers; it is the responsibility of all members of staff who deal with healthcare technology. table (3-1) highlights some of the benefits of HTM. [1]

Table (3-1)**: Benefits of Healthcare Technology Management (HTM)**

No.	**Benefits of Healthcare Technology Management (HTM)**
1)	Health facilities can deliver a full service, unimpeded by non-functioning healthcare technology.
2)	Equipment is properly utilized, maintained, and safeguarded.
3)	Staff makes maximum use of equipment, by following written procedures and good practice.
4)	Health service providers are given comprehensive, timely, and reliable information on: - the functional status of the equipment - the performance of the maintenance services - the operational skills and practice of equipment-user departments - the skills and practice of staff responsible for various equipment-related activities in a range of departments including finance, purchasing, stores, and human resources.
5)	Staff control the huge financial investment in equipment, and this can lead to a more effective and efficient healthcare service.

3.1.2 Importance of Healthcare Technology Management in the Health System:

All health service providers want to get the most out of their investments. To enable them to do so, they need to actively manage health service assets, ensuring that they are used efficiently and optimally. All management takes place in the context of your health system's policies and finances. If these are favorable, the management of health service assets can be effective and efficient, and this will lead to improvements in the quality and quantity of healthcare delivered, without an increase in costs, figure (3-1) illustrates the Place of Healthcare Technology Management in the Health System. [1]

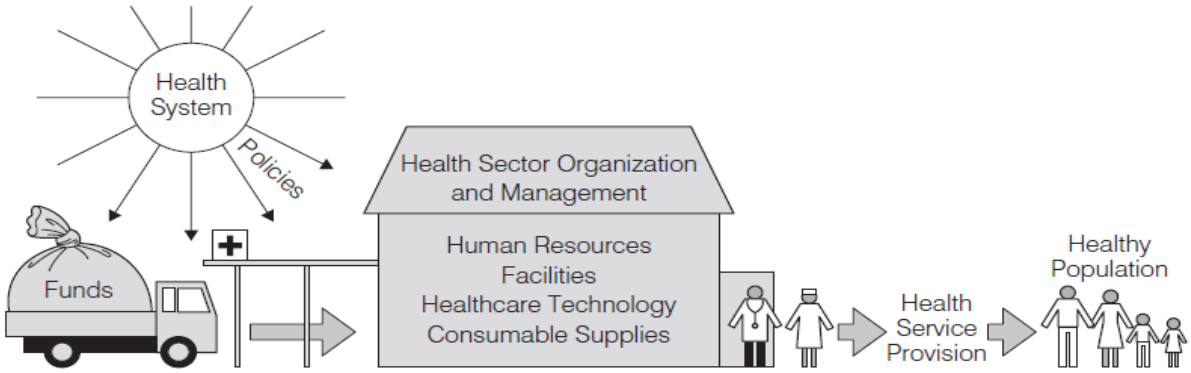


Figure 3-1: The Place of Healthcare Technology Management in the Health System

The health service's most valuable assets which must be managed are its human resources, physical assets, and other resources such as supplies. Physical assets such as facilities and healthcare technology are the greatest capital expenditure in any health sector. Thus it makes financial sense to manage these valuable resources, and to ensure that healthcare technology:

- is selected appropriately
- is used correctly and to maximum capacity
- Lasts as long as possible.

Such effective and appropriate management of healthcare technology will contribute to improved efficiency within the health sector. This will result in improved and increased health outcomes, and a more sustainable health service. And this is the goal of healthcare technology management. [1]

So, and depending on what is mentioned above we found that there is many important pillars in order to achieve effective HTM. And here we are going to focus on one of those pillars which is offering an Ideal work shop- module of World Health Organization (WHO) - to take care of all equipment in health institute in all aspects.

3.2 The Importance of Maintenance:

Healthcare technology is such an important part of healthcare today that it cannot easily be ignored. It has a very wide application: for example equipment is used to:

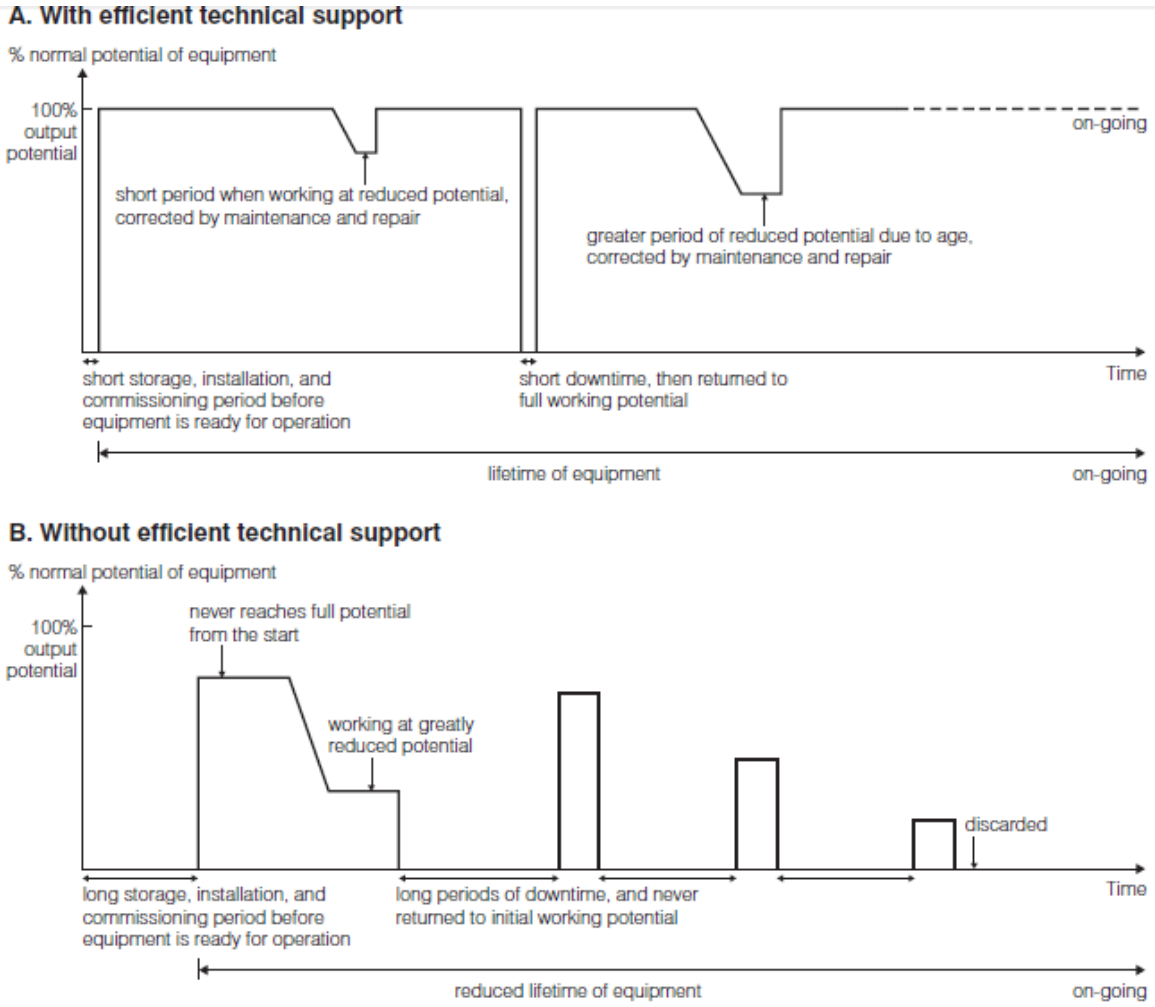
- help diagnose whether a patient has malaria
- treat a patient by removing their gall stones
- monitor the condition of a patient's heart
- provide therapy in order to get a patient moving about again.

All equipment has a life expectancy, just as each patient does. The life expectancy will be dependent on the type of equipment and the type of technology it contains. For example, five years might be the typical life for an ECG monitor, ten years for a suction pump, 15 years for an operating table, and 20 years for an electricity generator.

All equipment is made up of various parts – moving and non-moving, active and passive. At any time during the life of the equipment, these parts can fail due to wear and tear (this even applies to software). Thus, it is very important to give regular attention to the equipment through planned preventive maintenance (PPM) and corrective maintenance (repair).

Depending on how well equipment is looked after, the expected life can be achieved or cut short, as shown in Figure (3 -2). Thus maintenance is crucial to the 'life' of the equipment. If maintenance is not carried out regularly and on time, equipment will deteriorate to a state where it is beyond economical repair; in other words it costs more to repair it than to replace it. If maintenance does not occur at all, the equipment will grind to a halt.

Since equipment that is well looked after lasts a long time, it is important for maintenance to be seen as a collective responsibility in the health service. [1]



Adapted from: Mallouppas A, 1986, 'Background document for the WHO programme on maintenance and repair of hospital and medical equipment', WHO, Geneva, Switzerland, WHO/SHS/86.5

Figure 3-2: Potential and Life of Equipment with and without Maintenance

3.2.1 Maintenance:

Proper maintenance is essential to ensure that the equipment you have purchased continues to meet the standards required throughout its entire working life.

Aspects of the maintenance work may be affected by the country and health service provider through an existing regulating principles and conditions.

Undertaking maintenance belongs to the service provision function of health systems, and could therefore, in principle, be carried out by the government, the private sector, or by a mixture of the two.

Maintenance is required for all types of healthcare technology (workshop equipment). This requires a broad spectrum of skills to cover areas such as medical electronics, electro-medical systems, carpentry, plumbing, bricklaying, electrical installations, mechanics, refrigeration, automotive work, and technical management. The range of skills present in your HTM Service will depend on the type of health service provider you work for, and the other maintenance arrangements available in country.

It is useful to organize the maintenance system along similar lines to the health service provision already existing in country. For instance, if the health sector is predominantly run by the government, it is probably simplest to let the government run the maintenance organization as well. In contrast, if private organizations run the health services, it makes little sense for the maintenance activities to be carried out by a government body. In the majority of cases, a mixed system is most likely.

However, the government may wish to take a regulatory role and establish regulations which guarantee that healthcare technology performs effectively, accurately, and safely. The rules established are valid for all health service providers, irrespective of their type of organization.

Specific maintenance requirements would not need to be prescribed by the regulatory body. Instead, it is up to individual health service providers to decide how these will be provided. However, the nature and the complexity of some maintenance services often call for partnerships between the public and private health service providers. Partnerships may also exist between health service providers and private sector sources of maintenance support.

To provide maintenance services, the good links will normally need to be established between maintenance workshops. This will create a network that supports the needs of all determined health facilities. Maintenance is, of course, only one of many HTM activities that need to be carried out.

However, the fact that maintenance workshops usually already exist in most countries serves as a useful starting point for establishing a physical HTM Service across the health service provider organization and across country. [1]

3.2.2 Authorities Responsible for Maintenance:

If you work for a health service provider organization, you will need to conform to:

- Any regulations and guidelines concerning maintenance produced by the central management body.

In some countries, other agencies have been given the authority for the maintenance of certain types of equipment. For example, in the government sector, the Ministry of Works may be responsible for health buildings, plant, and service supply installations, the Ministry of Supplies may be responsible for furniture and office equipment, and the Ministry of Transport for vehicles. Similarly in the nongovernment or private sectors, there may be a Maintenance Service and/or a

Logistics Division which have authority over different types of equipment.

In addition, there will be national electricity supply, water supply, and telecommunication authorities with varying responsibilities for different types of equipment. In this situation:

- You will need to follow the policies and guidelines of these other agencies
- You should not interfere with equipment outside your responsibility.

However, if large groups of equipment are not being cared for adequately by these other maintenance agencies, your health service provider may need to re-negotiate the responsibilities of the different agencies in order to ensure that all the equipment the health service relies upon is in good working condition.

Ideally, the health service provider should have overall management control of all its equipment. In reality, it can be difficult to coordinate and control staff from other maintenance agencies working on health facility sites. With many agencies involved, there is often a duplication of skills on site (such as welders, electricians, carpenters).

For this reason, it is sensible to ensure that your in-house HTM Service is multidisciplinary, and includes the broad range of technical skills (mentioned above) necessary to cover all different types of equipment. The staff members of such a multi-disciplinary service have one boss only (the health service provider), work together for the good of all the physical assets of a health facility and not just some of them, and pool their skills. [1]

3.2.3 Maintenance Structure in the Health Service Hierarchy:

Figure 4 shows the development of an organizational structure for the HTM Service. It starts with the simplest form of HTM Team at small facility level, which can operate whether a workshop exists or not, and is comprised of general members of health staff. The organization is then based on the idea of a referral network of HTM Teams with increasing levels of technical skills. Therefore, it is important that:

- such maintenance personnel are reflected correctly in the staffing structure (Organizational chart) of the health service.

Maintenance staffs need to report to a manager who has sufficient knowledge and authority to bring forward the needs of the maintenance service. Thus, the HTM Managers should be senior technical staff, and higher up the HTMS they should be professional engineers.

HTM Managers (at all levels) should preferably report directly to, and be members of, their Health Management Team. They should be seen as an equal to other sector managers such as administrators, and heads of medical services, and should not have to report through these officers but have direct access to top management.

HTM should be incorporated into the health management system, using HTM Working Groups at each level to advise the Health Management Team. **Appropriate members of the HTM Team should therefore be involved in management committees** at facility, district, regional, and central levels in order for:

- A technical viewpoint to be present in health planning decisions
- Equipment management to be seen as a collective responsibility for all health staff.

The organizational structure for the HTMS ; Figure (3-4) provides a professional reporting structure for technical staff. Thus, technical staff should:

- Work according to the policies of the Central HTM Team and Working Group which coordinates the HTM Service.
- Work according to the technical guidelines of the largest central workshop.
- Investigate the regulations developed by the maintenance services of other health service providers in your country. [1]

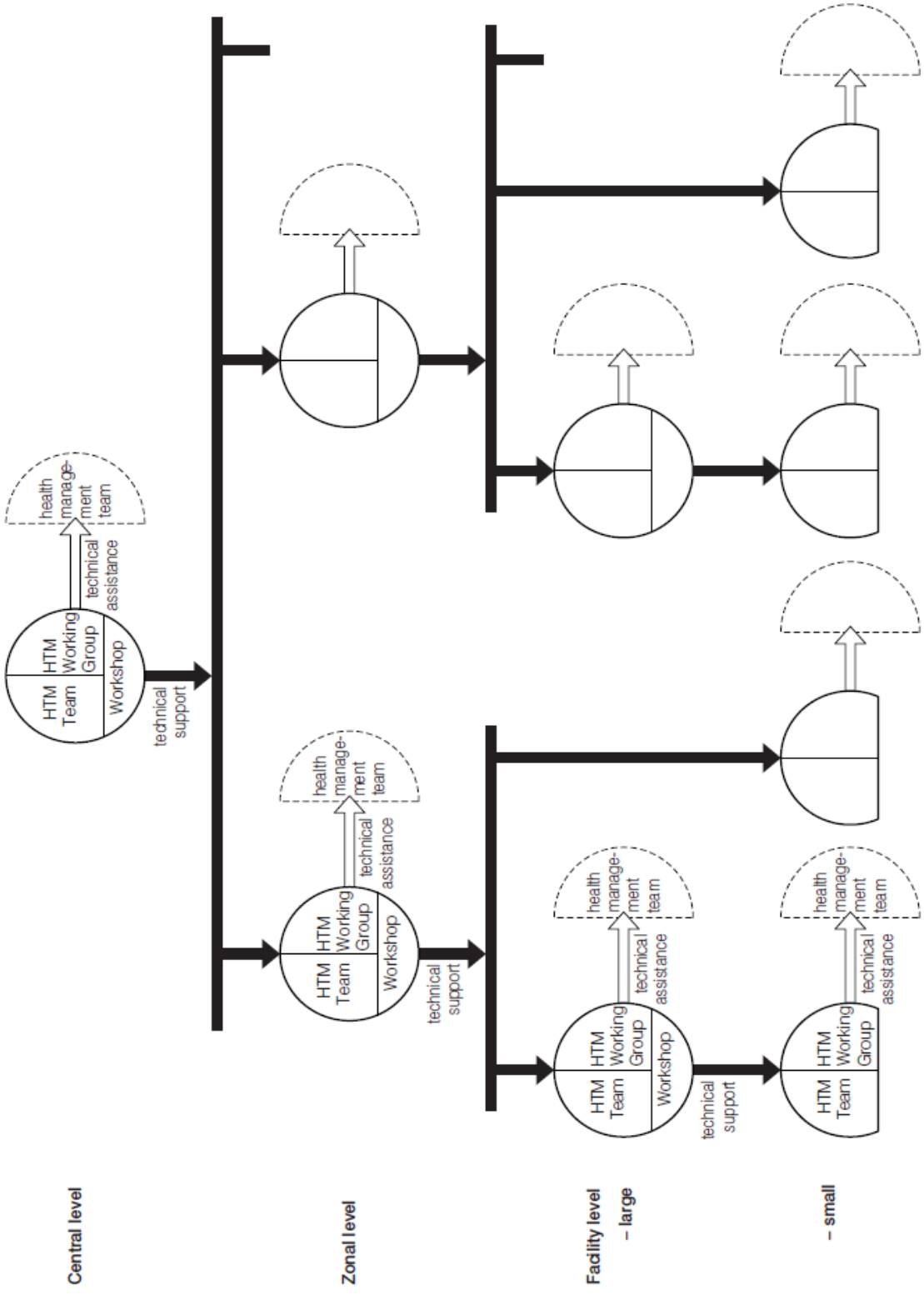


Figure 3-4: Sample Organizational Chart for the HTM Service

If maintenance staff in the organization are not adequately represented on management bodies, and have no professional service to take care of their

needs, it will be very difficult for them to be effective in their jobs. In this case, the health service provider should be lobbied to consider the role of maintenance staff and develop a suitable staffing structure for them within the health service. [1]

3.2.4 Establishment Posts:

It is very important that your organization creates suitable establishment posts for the members of the HTM Service. These are required so that staff can be recruited, hired, and placed in post in the first place. A well thought out structure of posts with different entry points, qualification requirements, salaries, etc., will also help with career progression. Many countries just starting to develop their HTM Service face great difficulties because they need technical staff but have no suitable posts, or because they hire them against other unsuitably-graded posts.

The HTM Service will require a range of different types of staff including general health staff (equipment users), artisans (craftsmen), technicians, technologists, engineers, and HTM managers, as well as support staff such as clerks, secretaries, stores persons, laborers, drivers, cleaners, etc.

The ability to develop posts for these individuals is dependent on negotiations with certain bodies. For example, in the government sector, a body such as the Public

Service Commission is involved. Similarly, in the non-government or private sectors, the personnel division or a department dealing with the structure of the organization will be involved. Therefore:

- You will need to follow the guidelines and procedures set by these bodies concerning suitable entry points and routes for career progression
- If there are insufficient posts for the HTM Service, the health service provider should be lobbied to establish a suitable structure.

Job descriptions are valuable tools for managers, enabling them to:

- Identify suitable candidates for each post.
- Make the best use of the staff available.
- Plan for further training.
- Recruit suitable people.

3.2.5 Staffing and Skills Levels:

If the health service provider wants to guarantee the good physical condition of its equipment, it needs to recruit enough staff, with the necessary skills, for the HTM Service. Adequate training for maintenance staff and managers is necessary to fill the wide variety of maintenance posts, and ensure specialists for many technical disciplines are available. It will be very difficult to ensure effective equipment maintenance without sufficiently skilled staff. Thus the organization will need to offer adequate recruitment packages so that technical staff can be retained in employment.

Ideally the HTMS will be able to pursue strategies to:

- Motivate their staff.
- Evaluate staff performance.
- Use staff appraisal as a positive tool to develop staff skills and enable career progression.
- Discipline staff when necessary.

In addition, the central level of the organization usually plays a significant role in, among other things:

- Developing training plans
- Organizing and providing training scholarships
- Approaching external support agencies to finance training programs.

Staff training needs should be addressed at every level by overall Equipment Training Plan. This is an ongoing program of in-service training. It will also need to develop a clear policy on what form of 'bonding' you will use to ensure that a member of maintenance staff sent for training remains with the health service on their return. Such conditions should cover both rewards for staying and liabilities for leaving. [1]

3.2.6 Maintenance Funding:

The work of the HTM Teams can only go ahead and be effective if adequate budgets are planned and allocated by the health service provider. These budgets need to cover all maintenance expenditure requirements, including the supply of:

- Spare parts.
- Tools.
- Other maintenance materials
- External maintenance contracts.

Health service provider can plan and budget for maintenance work. So, it will need to work within the financial resources allocated to it. In addition, the HTM Teams will have to follow the financial policies and procedures of the organization, in order to ensure that stock management and expenditure accounting is carried out according to the regulations.

Depending on the health service provider and country, the HTM Service may be able to generate income by charging for the services it provides. Whether this income can be used to improve the HTM Service further will depend on the accounting policies of the responsible finance authority, such as the treasury (in the government sector) or a central finance office. [1]

3.2.7 Maintenance Facilities and Resources:

If maintenance work is to be undertaken effectively, the health service provider will need to provide the facilities and resources that the HTM Teams require, such as:

- Sufficient secure workshop facilities (or maintenance rooms) equipped with suitable tools and test equipment; figure (3-5).
- Adequate supplies of maintenance materials and spare parts stocked in suitably located stores.
- Office space including adequate filing facilities and space for record-keeping.
- Adequate supplies of stationery for record-keeping.
- Adequate technical reference material and access to information.
- Adequate access to transport by maintenance staff so that they can carry out their tasks.

It will be very difficult to undertake the necessary maintenance work if this full range of resources is not available, and the health service provider will need to be lobbied to ensure they are provided. [1]

Figure 3-5: A part of workshop

3.3 Management of Tools and work facilities:

Tools are a very important ingredient for HTM Teams. Their availability in adequate quantities is the key to a successful maintenance program. Adequate working space and resources are also crucial for HTM Teams if they are to perform their work effectively. And this will provide the best working environment for HTM Teams.

3.3.1 Tools requirements:

Tools are capital items, can be very expensive, are paid for from the capital budget, and are usually only purchased annually.

3.3.1.1 Availability:

Various different tool kits should be available for the separate maintenance disciplines (painting, mechanics, refrigeration, etc.), and for different skill levels. For example, an electrician (at technician grade) uses a larger, more complex range of tools than an electrician's assistant (at craftsperson grade).

These tool kits should include hand tools; bench tools and safety testing instruments as well ; figure (3-6).

Once tools are purchased, it is imperative that they are looked after properly, are kept secure, and are inventoried, in order to ensure they are always available for use.

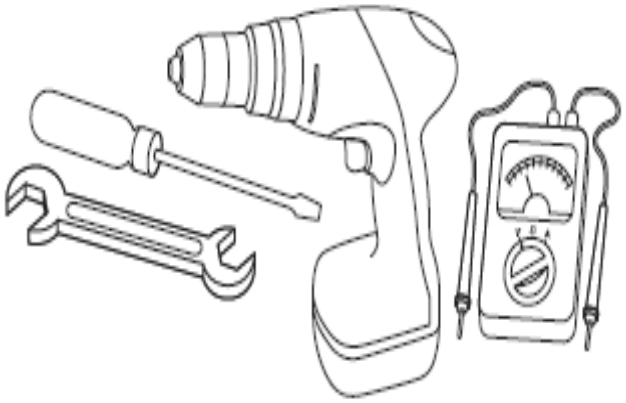


Figure 3-6: Various different tool kits

3.3.1.2 Finance:

If maintenance work is to continue, tools and test instruments must always be available. Thus, continually finding money for these items will be a challenge as long as a maintenance service exists. Hand and bench tools, and test instruments are important and sometimes complex pieces of equipment in their own right, and therefore can be very expensive items. [1]

3.3.1.3 Procurement Issues:

The quality and effectiveness of a repair job is often jeopardized by the use of low quality tools. Poor tools may break if they are not strong enough, they may fail earlier than expected, or they may rub, corrode, or in some way damage other parts of the machine. Even if you are experienced at using tools:

- Poor quality drill bits will break quickly.
- Spanners made to poor tolerances will rub the edges off nuts.
- Screwdrivers made of poor materials will destroy screw heads.

Cost and quality often go together. Well-known tool manufacturers often produce better products than companies making ‘lookalikes’. Many companies are set up solely for the purpose of manufacturing lookalikes – these products are often (but not always) cheaper, but may be of inferior quality. It is recommended that, in case of the items get more technically complex or critical, to try and buy better quality tools and test instruments. However, there may be an argument for buying lower quality tools at a much lower price, provided the tools can be replaced when necessary. [1]

3.3.1.4 Ownership and Replacement:

The health service provider needs to choose whether to purchase and own the tools themselves, or whether to rely on individual staff members to bring to work tools which are their own personal property in order to undertake their particular professional skills. Table (3-2) presents the advantages and disadvantages of both arrangements and many health service providers may use a combination of strategies. [1]

Table (3-2): Advantages and Disadvantages of Tool Ownership

The case	Advantages and Disadvantages
If tools are purchased by the health service provider	➢ They become health service property. ➢ Strategies must then be put in place to reduce loss and theft, and to penalize staff found abusing the tools. ➢ When tools reach the end of their life, there must also be a formal process where the production of a worn-out tool leads to it being decommissioned (like equipment), and a replacement bought through the normal purchasing programs of the health service provider.
If maintenance work relies upon staff members bringing their own personal tools to work	➢ When the individual leaves, the health service provider no longer has the tools required for the work. ➢ The health service provider also has to give the staff member a tools allowance so that he or she can replace each tool as it deteriorates due to the normal wear and tear caused by undertaking the daily work for the health service.

3.3.2 Security and storage system for tools:

There are many other issues to consider concerning tools, such as their security, access to them during different shifts, keeping track of them, loss and theft, disciplinary methods, etc. The action you take on all of these issues will depend a great deal on work culture in your country, and the experience you have had

with problems surrounding tools. Remember that tools are a valuable resource, and without them you cannot do your work. [1]

3.3.2.1 Issue and Responsibility:

Each HTM Team needs to have a Tools Inventory, which will be a subset of the Equipment's Inventory. This provides a detailed listing of all items, such as test and bench instruments, and the contents of tool kits, owned by, and located with, the HTM Team.

It is necessary to ensure the security of all tools belonging to each HTM Team/workshop. Also it is necessary to retain ownership of the tools within the health service if they own the tools, or guarantee the safety of personal tools belonging to staff.

Ultimately, the responsibility for tool security during working hours should fall to the staff using the tools. But the Health Management Team must provide adequate security measures for the working environment. It is important to remember that tools are attractive items to any opportunist thieves wandering around the health facility site.

Table (3-3) presents different levels of security to consider for tools. Different health service providers will use combinations of different strategies. There needs to be a balance between adequate access to tools so that work can continue, and sufficient security so that assets are not stolen (by the public or by staff). [1]

Table 3-3: Possible Security Strategies to Consider for Tools

Approach	Possible Security Strategies
Use a liberal Approach	➢ Find a suitable combination of security and adequate access for usual working methods. ➢ Avoid having workers signing everything in and out frequently, as this uses up a great deal of costly time. ➢ Lock away expensive items, such as oscilloscopes, and only issue them with a signature. ➢ Leave basic tools in view in the workshop, allowing for the immediate testing of a bright idea that a maintainer may have. ➢ Be wary of punishing staff for breakages – check whether they are breaking more tools because they are using them more often while undertaking more work than others. ➢ Trust staff to look after their tools. ➢ Introduce a level of security to the workshop premises in order to keep the inventory of tools secure from outsiders.
Use peer Pressure	➢ Make maintainers collectively responsible for tools and test instruments. ➢ If any are lost, make the entire HTM Team contribute to the cost of replacing them. ➢ Benefit from the peer pressure created – this helps to keep account of tools and works well.
Use a strict approach	➢ When not in use, hold all tools in a secure tool storeroom at the HTM Team's premises/workshop. ➢ Nominate a member of the HTM Team, such as the stores person, to be the 'authorized issuer of tools'. ➢ Restrict access to the keys for the tool storeroom to the HTM Manager and the nominated stores person. ➢ Each morning, make it the responsibility of the stores person to issue tool kits (or parts of them) to the relevant maintenance staff, necessary for the day's work. Both the stores person issuing the tool, and the individuals receiving tools, must sign for them in the Tools Ledger. This also provides an opportunity for making sure that all tools listed on the inventory are present in the tool kit. ➢ During the day, the maintainer who received and signed for the tools has sole responsibility for the tools he or she has been issued with. ➢ Keep specialized tools (hand or bench tools which aren't used

	regularly every day) in the tools store, and only issue and sign them out as and when required. ➢ At the end of the working day, everyone signs their tools back in with the stores person. This can also be an opportunity for making sure all tools signed out that morning have been returned in the same condition as when issued. ➢ At weekends or during call-outs at night: • Link access to tools to the duty roster. • Allow staff working outside normal working hours to keep tools with them to enable them to attend to call-outs without problems • Make them sign their tools back in with the stores person at the start of the next official shift. ➢ At the end of each week, the stores person checks to ensure that all tools are still present according to the Tools Inventory, and reports their findings to the HTM Manager.

3.3.2.2 Loss and Discipline:

It is inevitable that tools will be lost or damaged from time to time. Any such loss or damage will become evident at the end of each week when the Tools Inventory is checked. Tools which have become damaged due to normal wear and tear should not be charged to the signatory. However, your organization should consider what action will be taken if tools are missing or abused, and if particular individuals are the persistent cause of problems.

Your response to good and bad performance will depend on local human resources policies and procedures, your strategies for motivating staff, and whether you take a positive approach, a disciplinary approach, or a combination of the two.

One option is to take a positive approach which encourages good behavior. Staff that consistently treat their equipment well and take care of it are given a reward as an incentive. This could be the chance to attend a skills-development course, or perhaps nomination as a trainer of others: the strategies chosen would depend on the type of tools and skills involved.

For instance, individual staff members may be issued with tools that are checked once a week (or once a month). Anyone who has a complete toolbox every three (or six) months is given a bonus: some batteries for example, or the right to 'lose' an item without penalty. After five years, possibly the toolbox could become the property of the staff member.

Another option is to take a disciplinary approach, and establish mechanisms so missing and abused tools can be charged to staff. This method aims to make the signatory for tools more accountable for their actions. Such charges may be deducted from their salary by installments, or, in the case of more expensive items, penalties may be incurred in the individual's terminal benefits. Persistent offending may result in termination of employment.

Such a system, if adopted, must be fair: only tackle individuals who abuse or steal tools intentionally. Each case should be assessed individually, using formal disciplinary hearing procedures. Finance and salary departments should base fines on realistic quotes for replacing the tools.

However, any approach taken to enforce rules for maintenance staff is only workable if it takes place in the right working environment, otherwise petty tyranny may prevail. Help to make staff more accountable by clearly setting out their responsibilities towards tools. The most important thing is for staff to be in an environment where their managers are present, involved, expect the correct results, and are seen to perform well themselves. [1]

3.3.2.3 Storage of Tools:

It is useful to have an organized way of storing tools rather than just a jumbled heap of items. Your strategies will depend on:

- Your tools policy
- Whether your tools are kept out in the open in the maintenance premises/workshop or locked away in a secure tool storeroom
- How much travelling your staff do, such as maintenance by outreach
- When tools must be available, such as during a night shift.

Table (3-4) presents a variety of initiatives that different technical teams have used. [1]

Table (3-4): Various Initiatives for Storing Tools

Type of Storing Tools	Description
Steel tool boxes	These contain cantilevered trays and usefully store items such as a mechanic's or electrician's hand-tools.
Canvas carry-all bags	These usefully store items such as a carpenter's or painter's hand-tools.
Wall-mounted boards	These contain hooks and nails and loops positioned appropriately so that tools can be hung up – possibly with the outline of the tool drawn on the board so that it is obvious where each tool should hang and which ones are missing.
Lockable tool cupboards	These contain shelves for test instruments and sets (such as Allen keys and socket sets), as well as hanging spaces for tools (as described above).
Lockable wooden or metal storage boxes	These can be stored, and even bolted down, in the back of a van or mobile workshop for outreach work figure 7.

It is useful to remember that how you position and mount your bench tools will affect how well you can use your workshop space. [1]

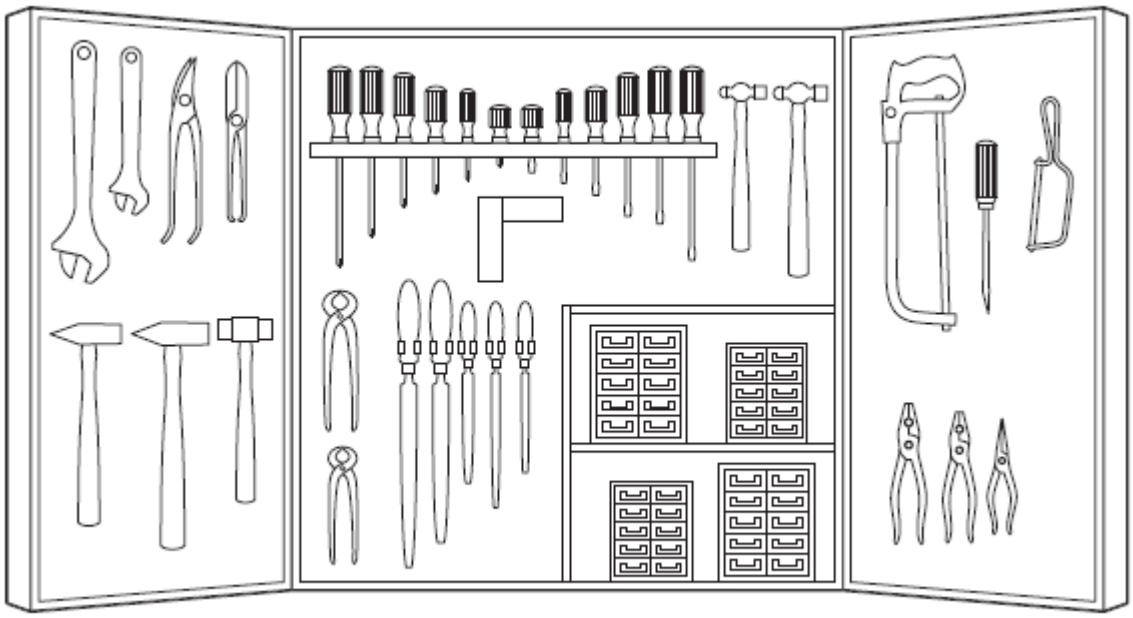


Figure 3-7: Lockable storage boxes

A **Tools Ledger** can be designed to ensure that it is possible to always know where tools are and who has them, even when staff work off site (for example, at staff accommodation), or on outreach trips over a period of days.

It is suggested that the Tools Ledger be a book rather than pieces of paper which are filed, since sheets of paper detailing who signed for a tool can easily go missing. For larger HTM Teams and workshops which have separate sections for different maintenance disciplines (carpentry, electrical, plumbing, medical, etc.), a Tools Ledger can be kept for each discipline. This makes it easier to keep track of tools under the responsibility of different work teams.

The Tools Ledger book should be divided in two. This way it can be a record of the issuing of tools as well as a checklist inventory of the tools for that maintenance section. The two halves work as follows:

- The front of the book is used as a Tools Issue Register with a double-page spread to record the use of tools daily (or weekly, depending on the level of security chosen – see Box 3). An example of how it can be laid out is shown in Figure 8.

- The back of the book contains a list of all the tools owned by that maintenance section (the bench tools, the contents of the various hand-tool kits, and the test instruments), to act as an inventory of the tools. Against this list there are weekly (or monthly) columns, where ticks are placed if the tools are present at the end of-week (or month) check.

OUT						IN			
Date	Qty	Item	Storekeeper's signature/ initials	Technician taking tools out	Technician's signature	Date	Signature of technician returning tools	Storekeeper's signature/ initials	Remarks
6/4	1	Saw	JK	CC	C.Chandle	6/4	C.Chandle	JK	In good condition
7/4	2	Multimeter	JK	WK	W. Khan	7/4	W. Khan	JK	Left at Doctor's house
						8/4	W. Khan	JK	Multimeter returned

Figure 3-8: Suggested Format for the Tools Issue Register

This is an example of a possible layout for the double-page spread within an A4 book which can act as the Tools Issue Register, with an example included of the type of entries. Large HTM Teams could set up a book for each different maintenance discipline.

3.3.3 Managing the Work Space:

The design and layout of workshops varies depending on the size of the HTM Team and what their responsibilities are. However, most agree on the various elements required, as follows:

- Different working areas for different maintenance disciplines. For example, welding, electronic, mechanical, and carpentry. (Note: because medical equipment maintenance work is much finer and more delicate than for other items, medium to large health facilities will require a separate dedicated workspace that can be kept clean for this work).
- Suitable work-benches, storage cabinets, stools, etc. for each work area.
- Secure storerooms for spare parts and bulk deliveries of raw materials.

- An office area with desks, filing cabinets, noticeboard, shelves for the library, etc.
- Changing rooms with lockers, benches, shower, toilet, etc.
- Cleaning/draining areas with a sink.
- Shaded outside working areas for handling larger items and raw materials, or for dirty jobs, a vehicle pit, etc.
- Secure outside storage areas for gas bottles, decommissioned equipment awaiting disposal, etc.
- Vehicle access.

Figure (3-9) presents a diagram of a workshop layout which includes most of these elements; figure (3-10) illustrates a Typical Layout for a Workshop of a 50-Bed Hospital, figure (3-11) shows a typical Layout for a District Workshop and figure (3-12) shows a Layout of a Zonal Workshop Covering an Association of Health Service Providers.

It is useful to remember that how you position and mount your bench tools affects how well you can use your workshop space. When planning the layout of your workshop, it is important to consider how the staff do their work. A great deal of time and energy can be wasted, and traffic-jams caused, by poor placement of bench tools.

An example of a bad layout is shown in Figure (3-13) where:

- The plumber enters the workshop with long lengths of pipe and travels to the far side of the room to reach the pipe cutter (getting in everyone else's way)
- Then takes the shorter pieces diagonally across the room to reach the grinder (passing through other people's work areas)
- Then moves the pieces to another bench to get access to a vice to use a die for threading. It may be beneficial to discuss your needs with an architect in order to get a space that works well.

Other requirements for workshops are:

- Adequate manuals and technical literature.
- Sufficient protective clothing, such as gloves, overalls, goggles, boots, etc.
- Safe storage of hazardous materials, such as gas, oil, chemicals, etc.
- Correct disposal methods for maintenance waste. [1]

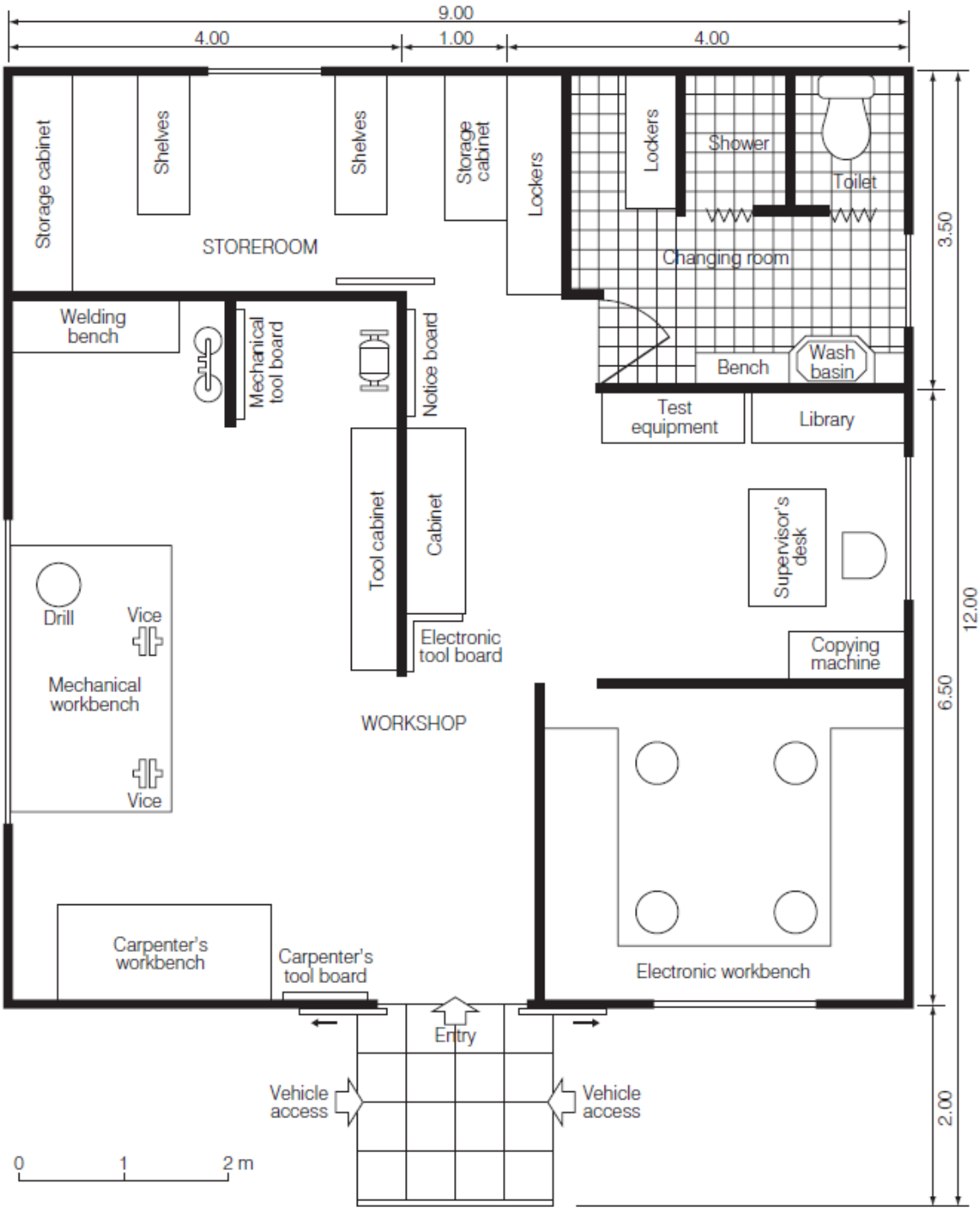
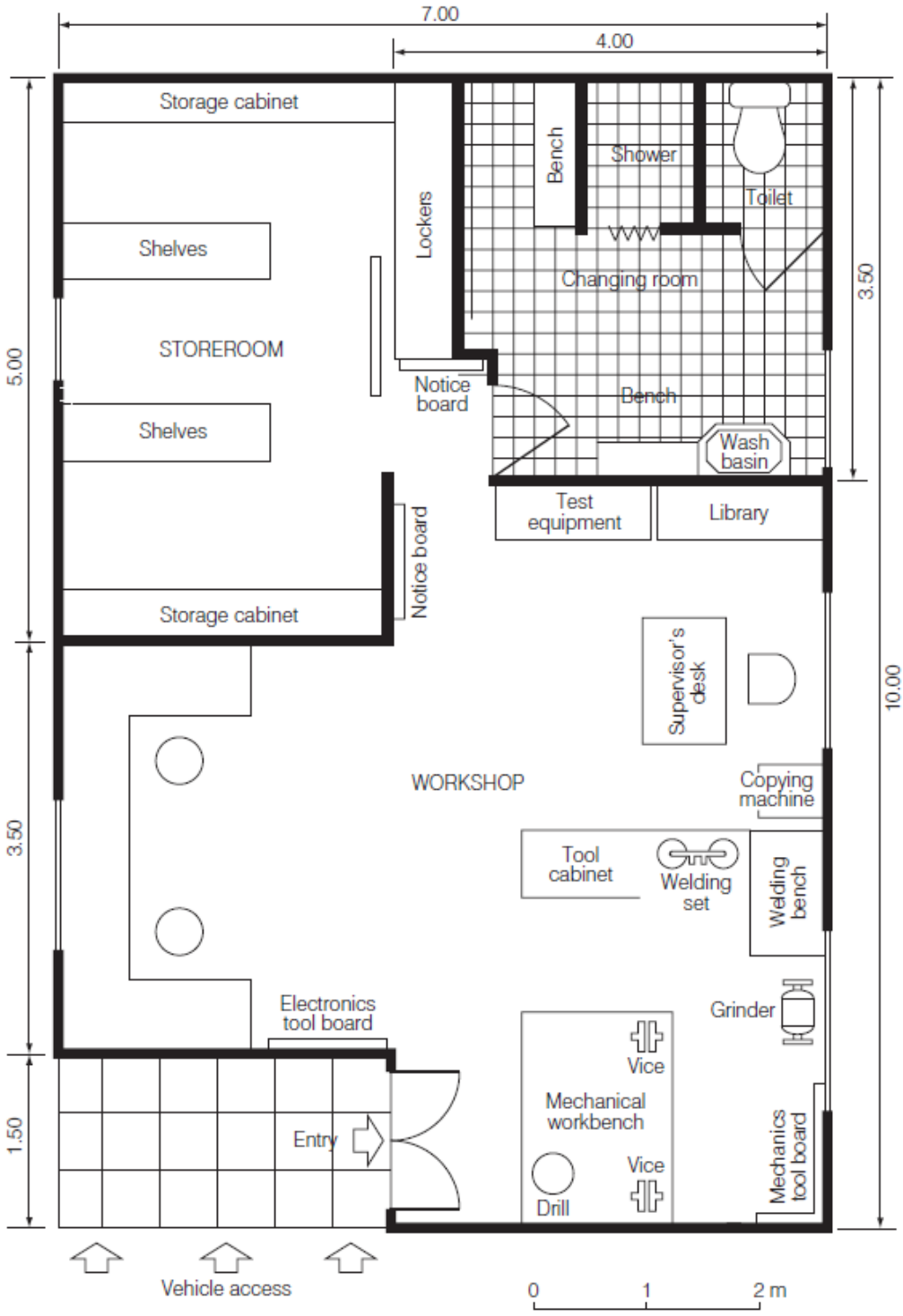


Figure 3-9: Typical Layout for a Workshop of a 100-Bed.

Source: WHO Regional Office for the Western Pacific, 1996, 'District hospitals: guidelines for development', 2nd edition, Western Pacific Series No.4, WHO Regional Publications, Manila, Philippines



. **Figure 3-10: Typical Layout for a Workshop of a 50-Bed Hospital.**

Source: WHO Regional Office for the Western Pacific, 1996, 'District hospitals: guidelines for development', 2nd edition, Western Pacific Series No.4, WHO Regional Publications, Manila, Philippines

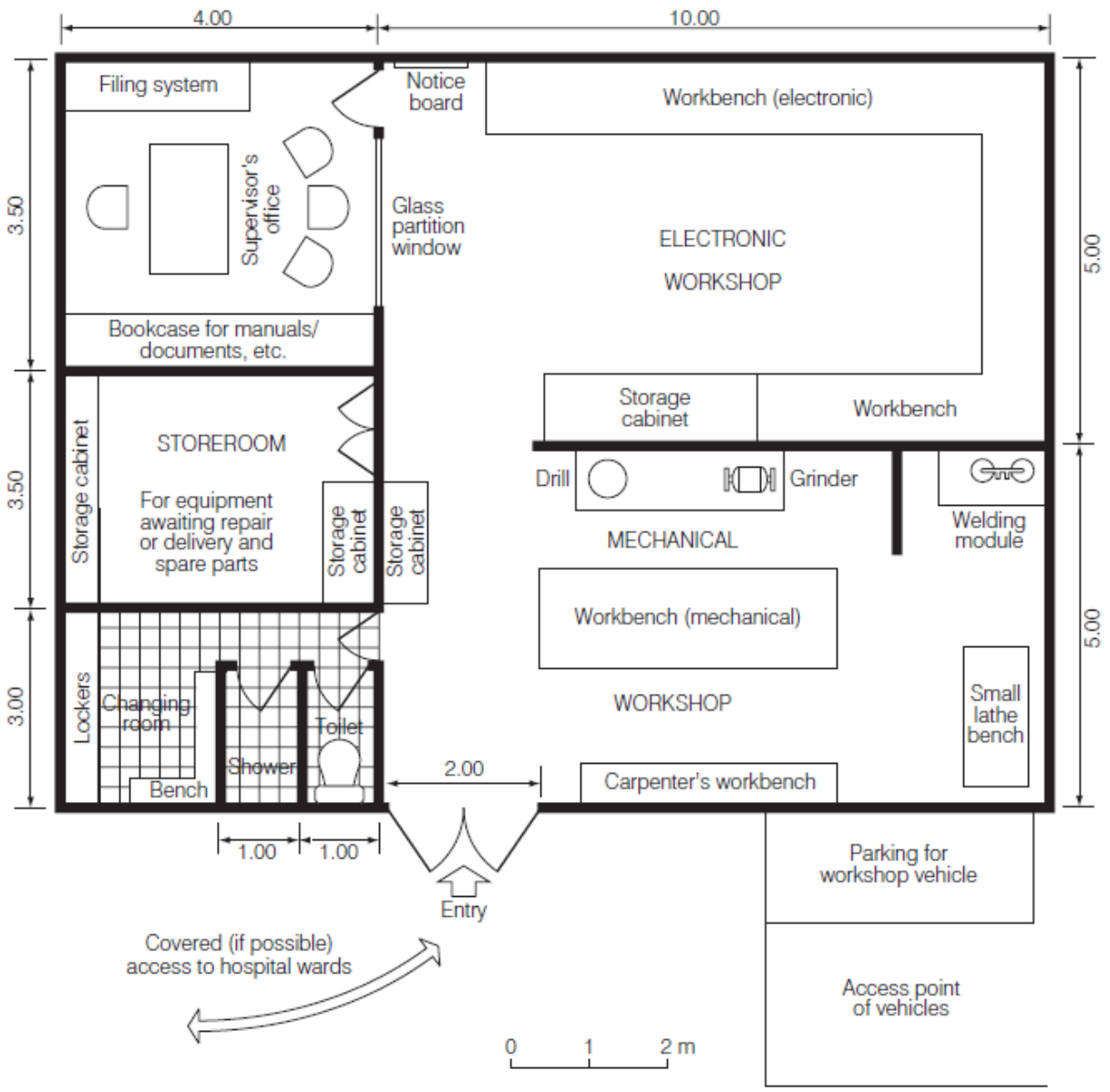


Figure 3-11: Typical Layout for a District Workshop

Source: Mallouppas A, 1986, 'Background document for the WHO program on maintenance and repair of hospital and medical equipment', WHO, Geneva, Switzerland, WHO/SHS/86.5

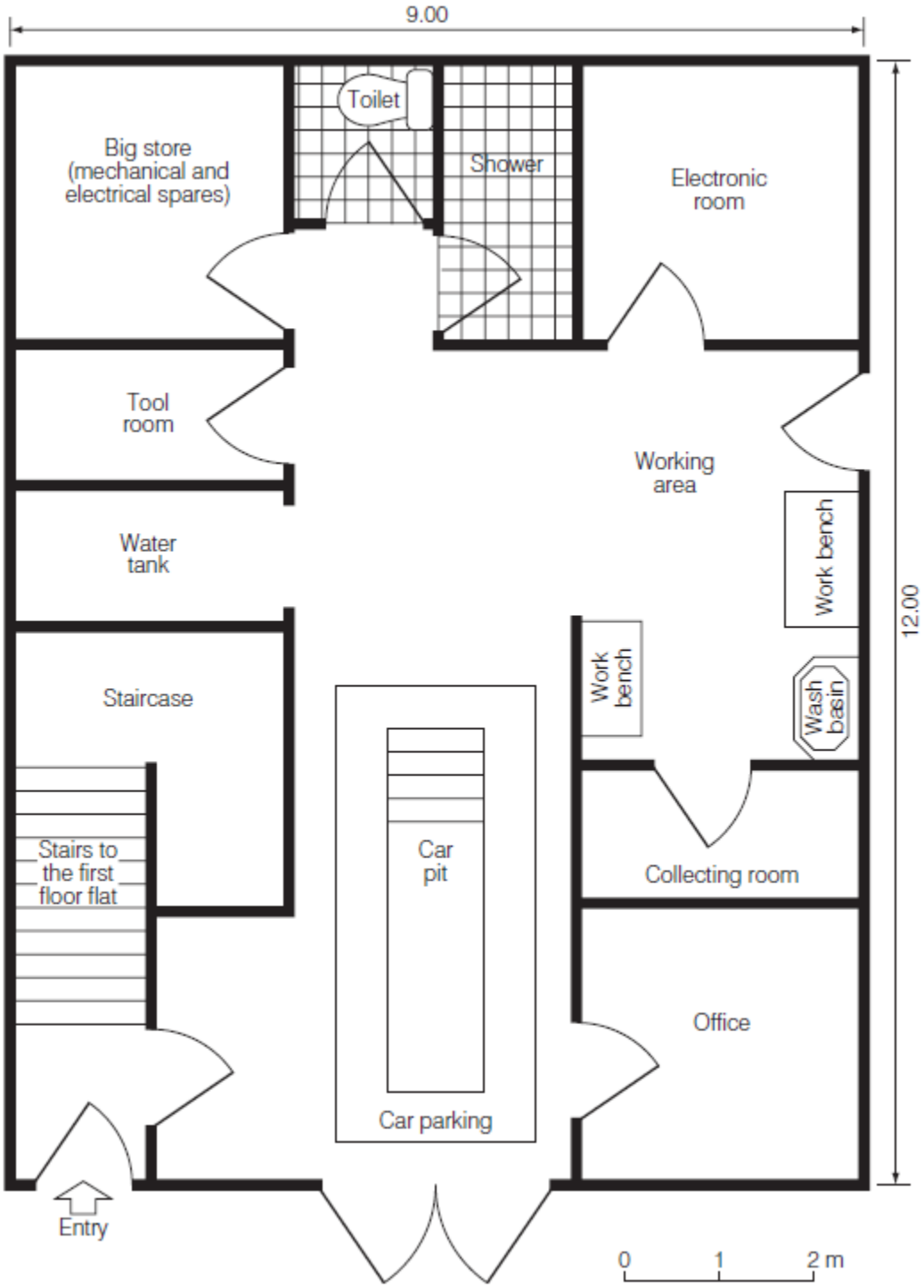


Figure 3-12: Layout of a Zonal Workshop Covering an Association of Health Service Providers
Source: FAKT, 1998, 'International seminar for hospital technicians/engineers, 28 January to 7 February 1998, Moshi, Tanzania', FAKT Publication, Stuttgart, Germany

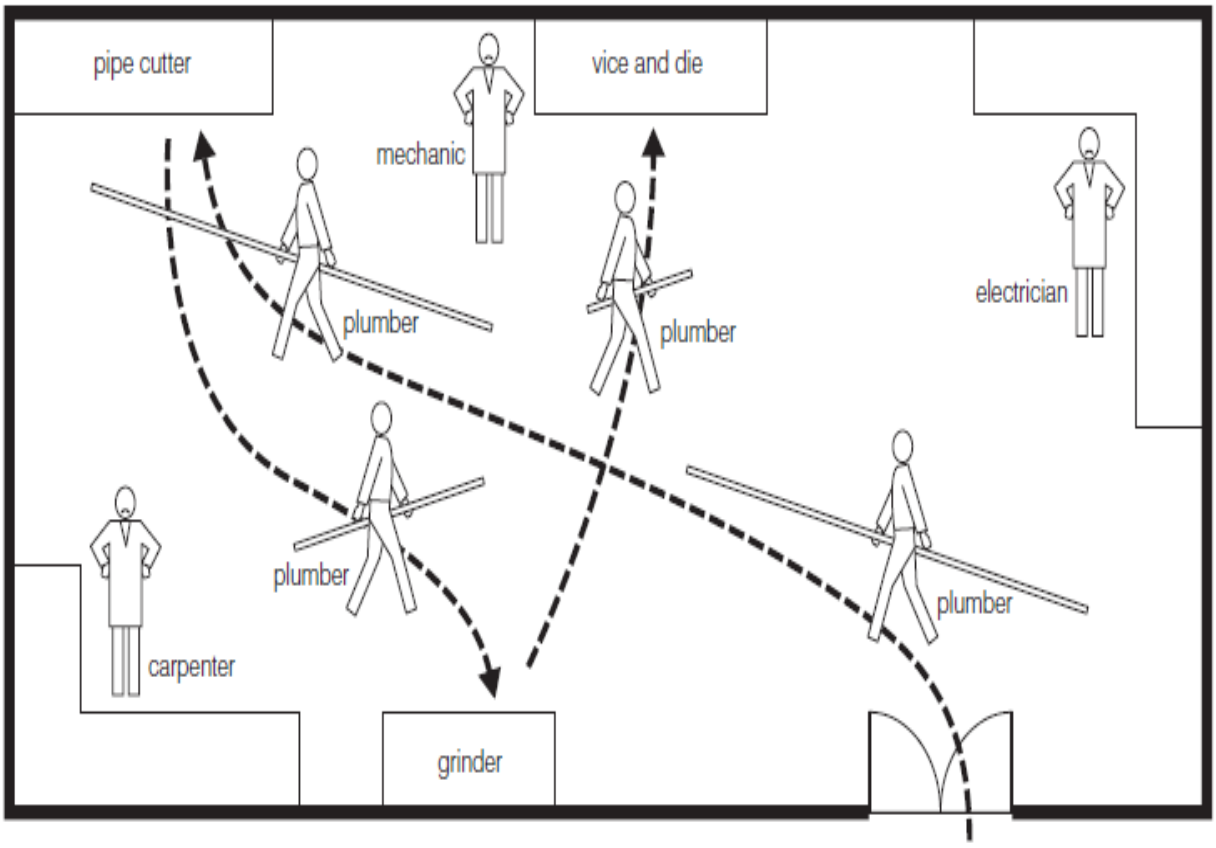


Figure 3-13: Example of the Problems of a Poorly Laid Out Workshop

Chapter Four

Methodology

4.1 Study Design:

This study is a kind of descriptive study which describing the current situation at biomedical workshop in some of Khartoum states' hospitals; taking into our consideration the standards of WHO and Jordanian one.

4.2 Study Setting:

Thirty samples of governmental hospitals were considered in this study because they cover a wide area of population. And the normal distribution will appear through these samples.

4.3 Sample's Process:

Firstly, we design a structured visual inspection sheet and it is controlled with Dr.Elias Siddig Mohamed and Dr.Afraa Hashim. Then we delivered this sheet to biomedical engineers at hospitals under study.

Secondly, we measured the dimensions of current workshops and draw them using ArchiCAD to compare between the actual workshop and the ideal one.

Furthermore, we do an awareness of the concept of Health Technology Assessment (HAT) for some biomedical engineers during collecting data.

4.4 Research Limitations:

Only twenty two of thirty samples have workshops, so we have a result of these twenty two samples.

4.5 Block diagram of methodology:

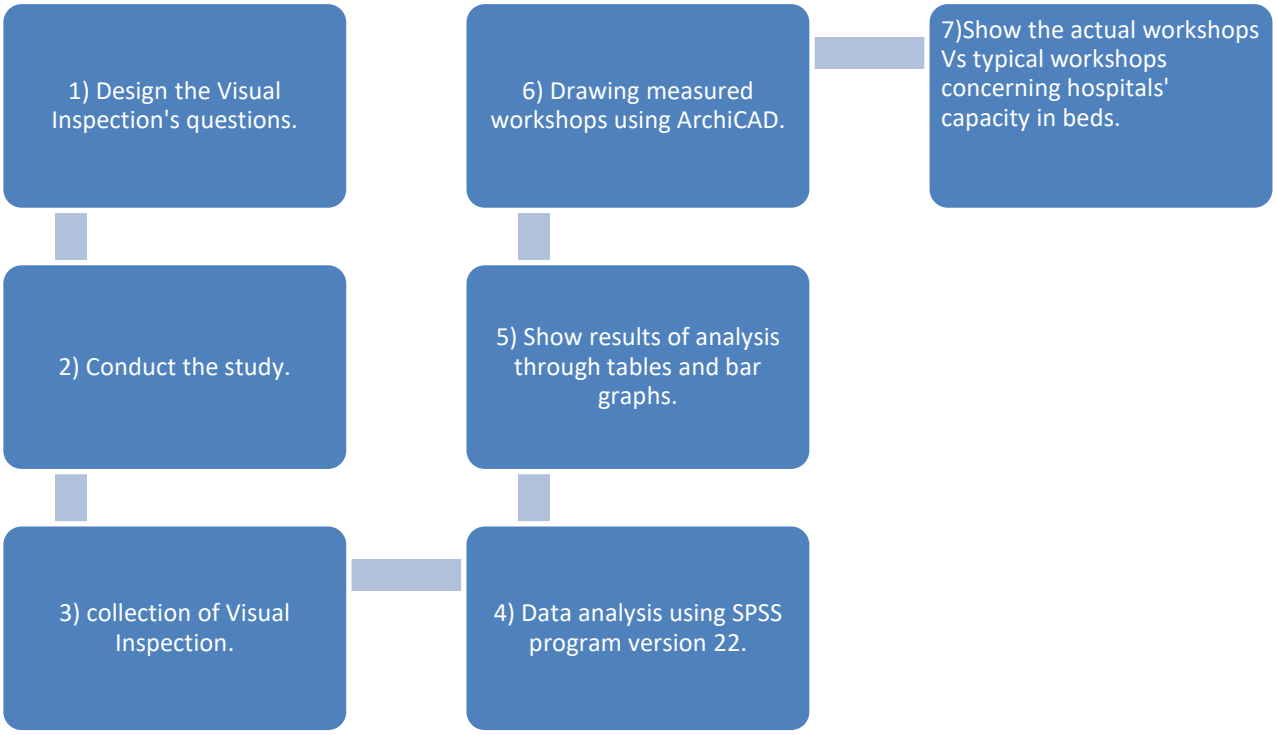


Figure 4-1: Block diagram of methodology

4.6 Analysis:

After finishing from collecting data at hospitals under study, it is analyzed to reflect the current situation of these hospitals. Also to show and determined the weak points which exist currently and make use of this analyzed data to come up with the best design of biomedical work shop.

In this study we used SPSS program version 22 for analyzing collected data. So, the following descriptive tables illustrate the situations at selected workshops:

Table 4-1: Years of professional experience

professional experience	Frequency	Percent
Less than 5 years	7	23.3
5-10 years	6	20.0
More than 10 years	12	40.0
None	5	16.7
Total	30	100.0

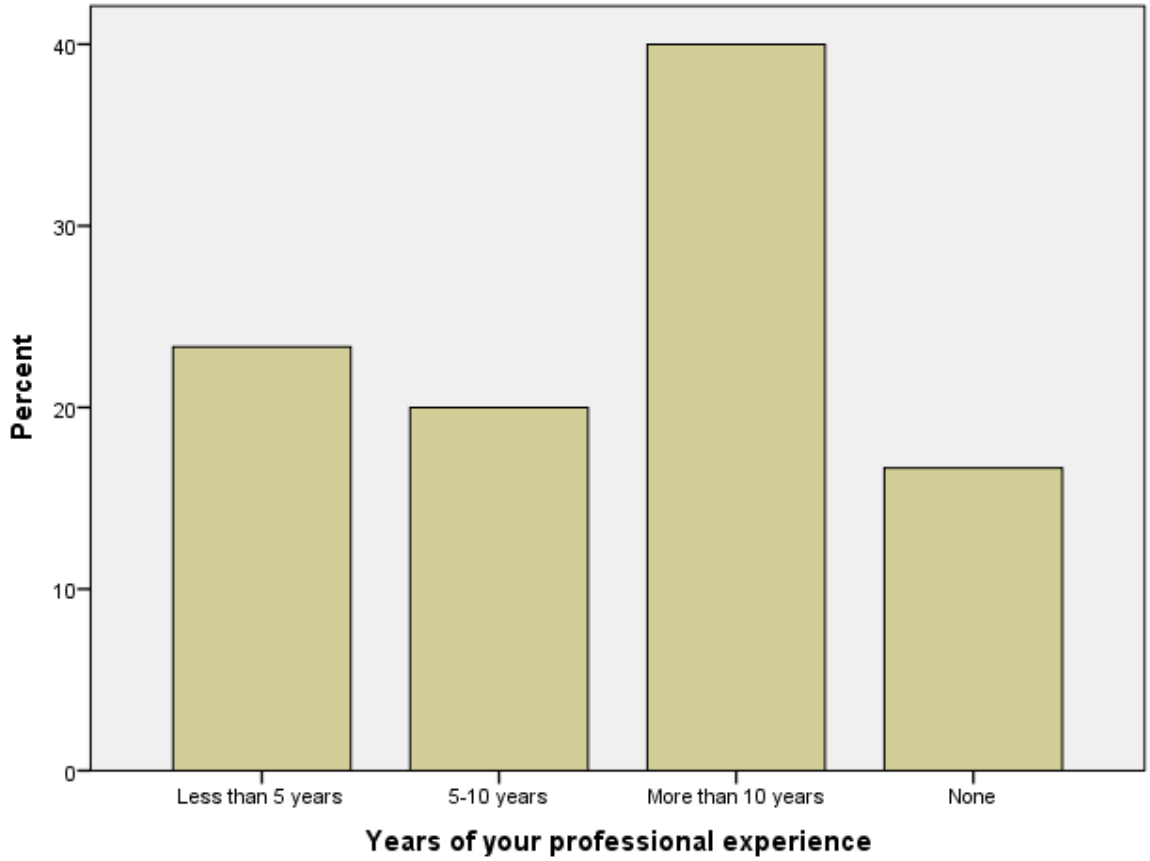


Figure 4-2: Years of professional experience

Table (4-1) and figure (4-2) show that, the difference in years of professional experience between hospitals. So, 40% of biomedical engineers have more than ten years of professional experience.

Table 4-2: Full operating capacity of the hospital (in beds)

operating capacity (in beds)	Frequency	Percent
Less than 50	2	6.7
50<100	3	10.0
100<200	7	23.3
More than 200	13	43.3
None	5	16.7
Total	30	100.0

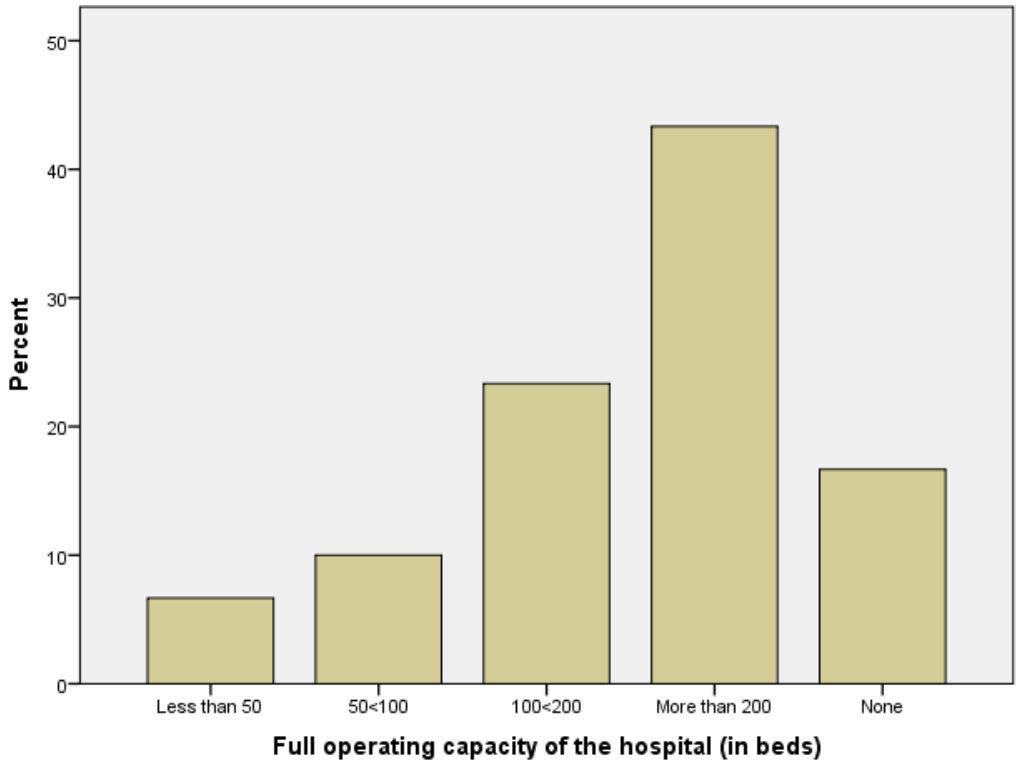


Figure 4-3: Full operating capacity of the hospital (in beds)

Table (4-2) and figure (4-3) illustrate that, 43.3% of hospitals their full operation capacities (in beds) are more than 200 beds.

Table 4-3: Is there an ideal biomedical workshop at hospital

Availability of ideal biomedical workshop	Frequency	Percent
Yes	3	10.0
No	21	70.0
None	6	20.0
Total	30	100.0

Figure 4-4: Availability of ideal biomedical workshop

Table (4-3) and figure (4-4) clarify that, 70% of hospitals under study have no ideal biomedical workshop.

Table 4-4: Number of employee(s) in biomedical workshop

Number of employee(s)	Frequency	Percent
One	3	10.0
Two	7	23.3
Three	5	16.7
Four	3	10.0
Five	1	3.3
More than five	6	20.0
None	5	16.7
Total	30	100.0

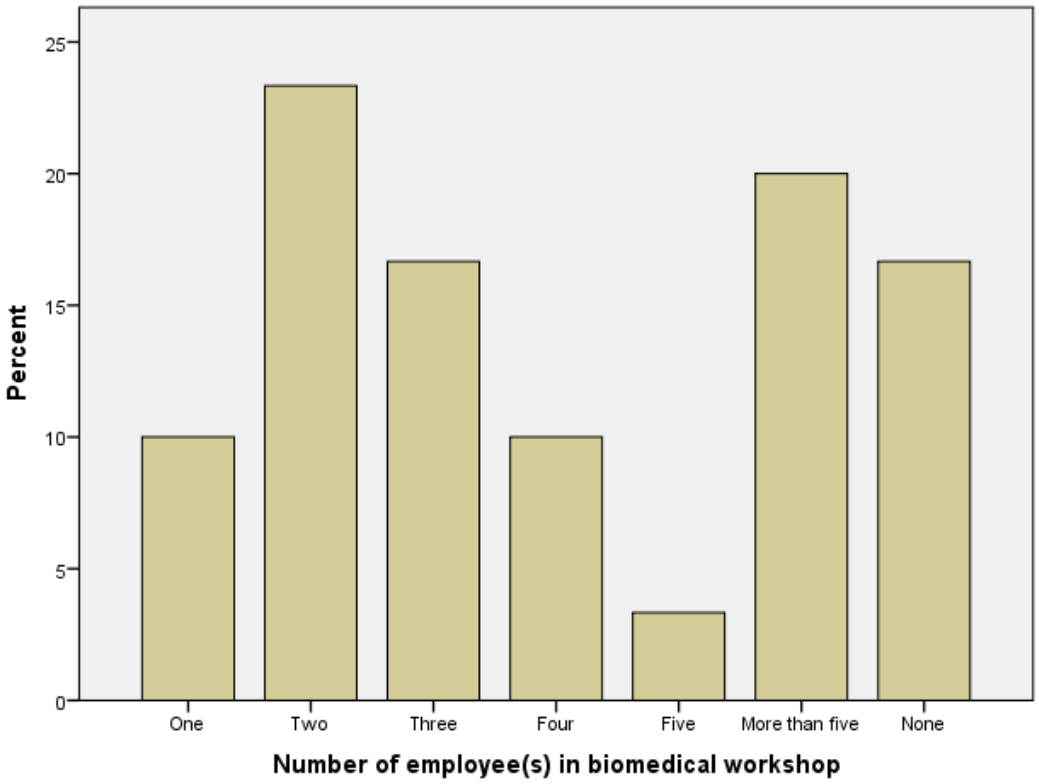


Figure 4-5: Number of employee(s) in biomedical workshop

Table (4-4) and figure (4-5) explain that, the highest percent of employees' number goes to two biomedical engineers (23.3%) while 16.7% of hospitals have no biomedical engineers. So, it is difficult for them to monitor all equipment at hospital in proper way.

Table 4-5: Do you have clinical Eng. specialty at your biomedical workshop

Have clinical Eng.	Frequency	Percent
Yes	25	83.3
None	5	16.7
Total	30	100.0

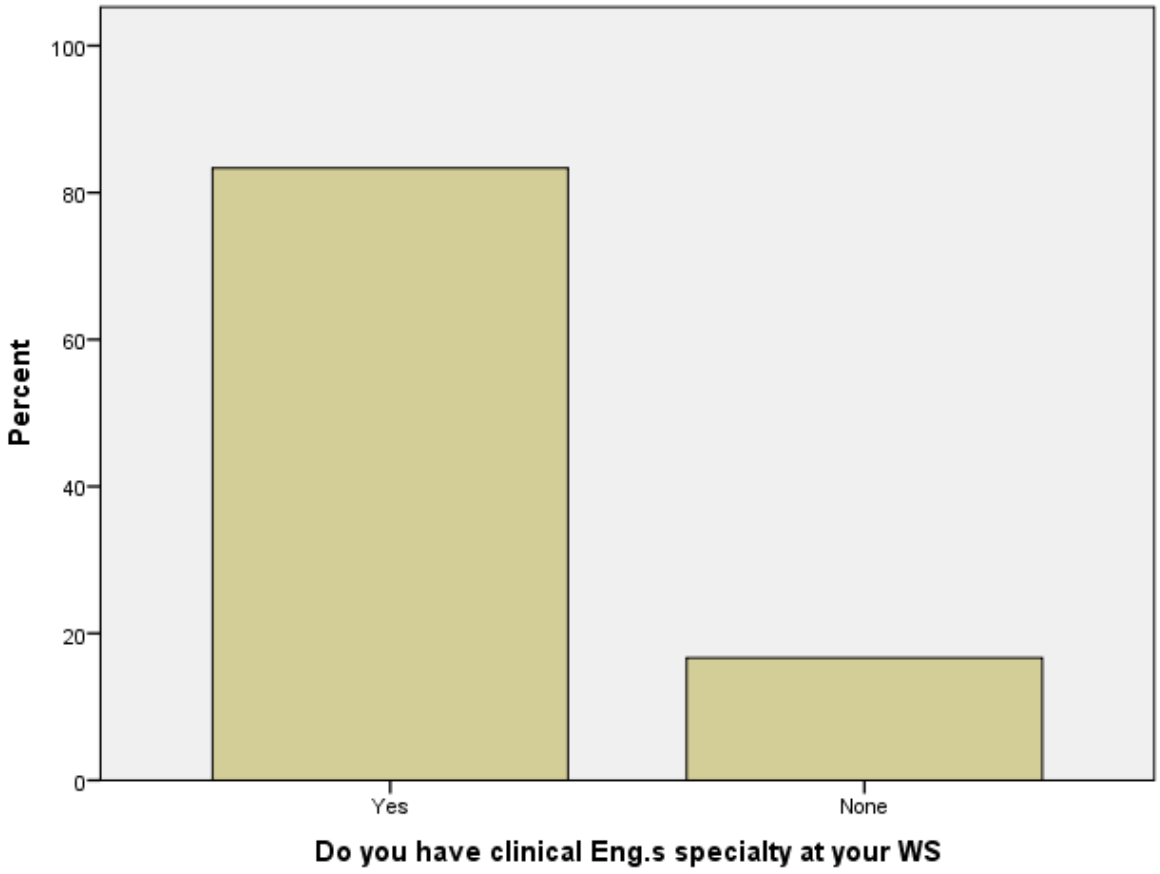


Figure 4-6: Have clinical Eng.

Table (4-5) and figure (4-6) show that every hospital has workshop has at least a clinical engineer and this represents 83.3%

Table 4-6: Do you have electrical Eng. specialty at your biomedical workshop

Have electrical Eng.	Frequency	Percent
Yes	5	16.7
No	20	66.7
None	5	16.7
Total	30	100.0

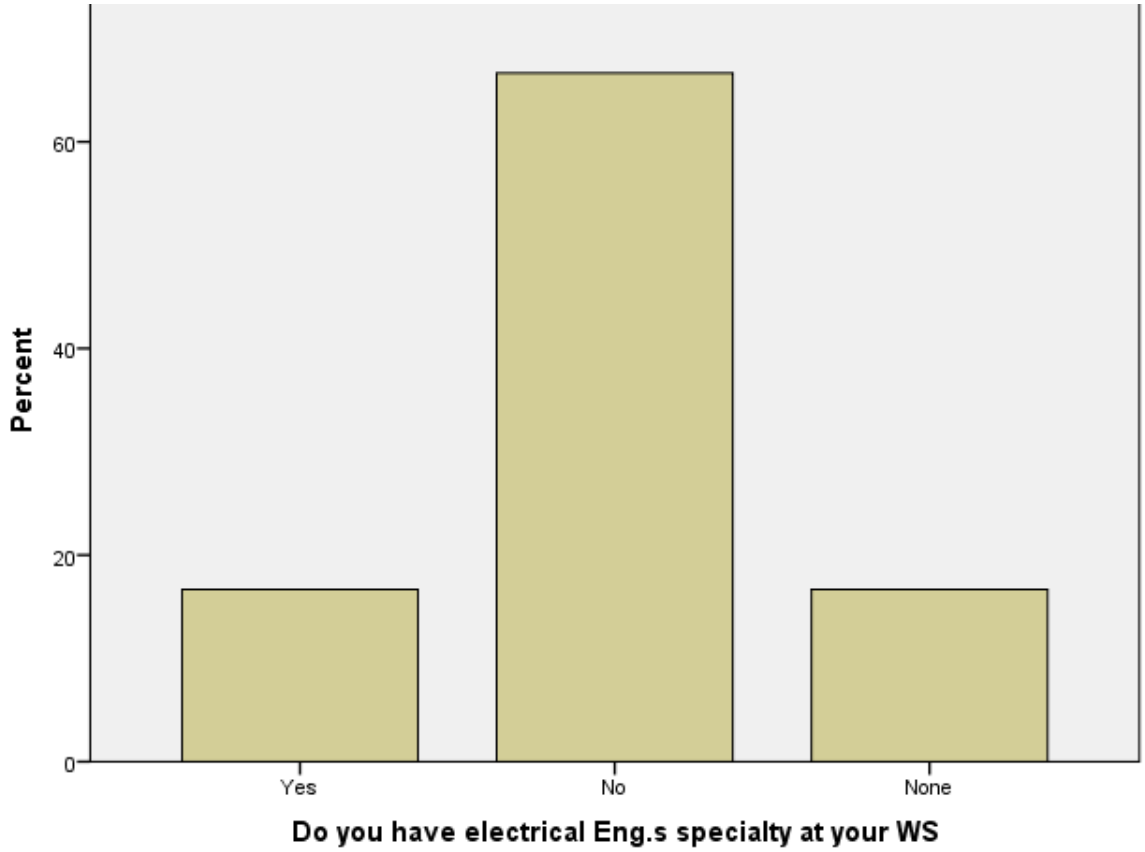


Figure **4-7: Have electrical Eng.**

On the contrary Table (4-6) and figure (4-7) illustrate that 66.7% of hospitals have no electrical engineer.

Table 4-7: Do you have technician(s) at your biomedical workshop

Have technician(s)	Frequency	Percent
Yes	13	43.3
No	12	40.0
None	5	16.7
Total	30	100.0

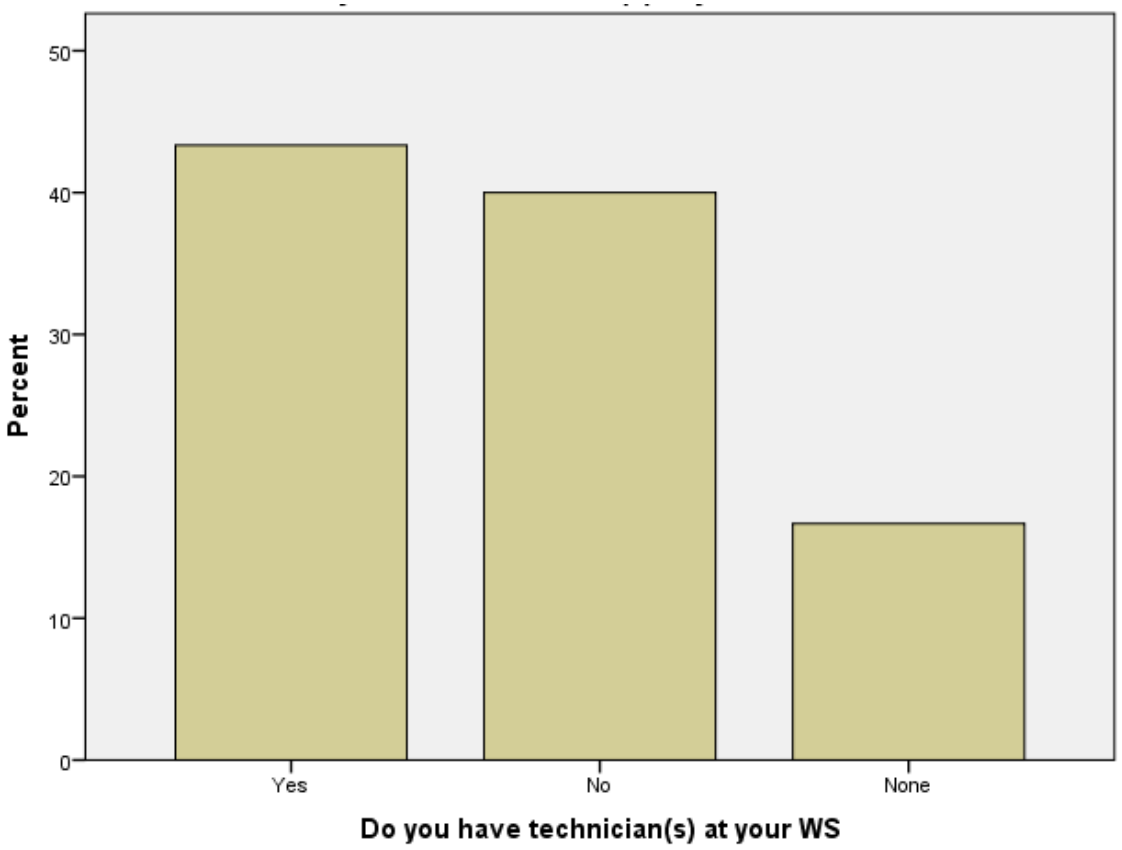


Figure 4-8: Have technician(s)

Table (4-7) and figure (4-8) describe that, the percentage of hospitals have technician (s) 43.3% and hospitals have not technician (s) 40.0%.

Table 4-8: %Effectiveness of current workshop

%Effectiveness	Frequency	Percent
20%	4	13.3
30%-50%	8	26.7
60%-90%	11	36.7
More than 90%	2	6.7
None	5	16.7
Total	30	100.0

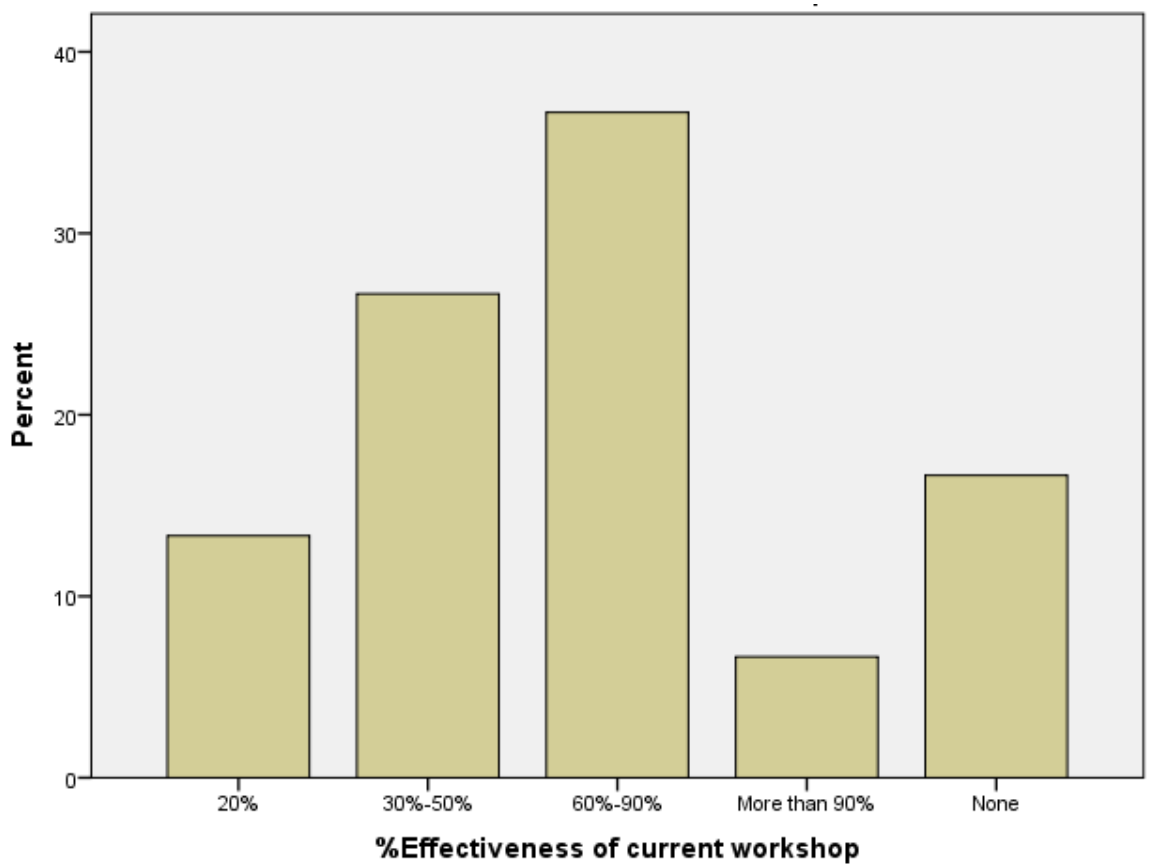


Figure 4-9: Effectiveness of current workshop

Table (4-8) and figure (4-9) reflect the effectiveness of current workshop. So, 36.7% of hospitals their effectiveness is (60%-90%).

Table 4-9: %Awareness of Health Technology Assessment

%Awareness of HAT	Frequency	Percent
20%	12	40.0
30%-50%	5	16.7
60%-90%	6	20.0
More than 90%	2	6.7
None	5	16.7
Total	30	100.0

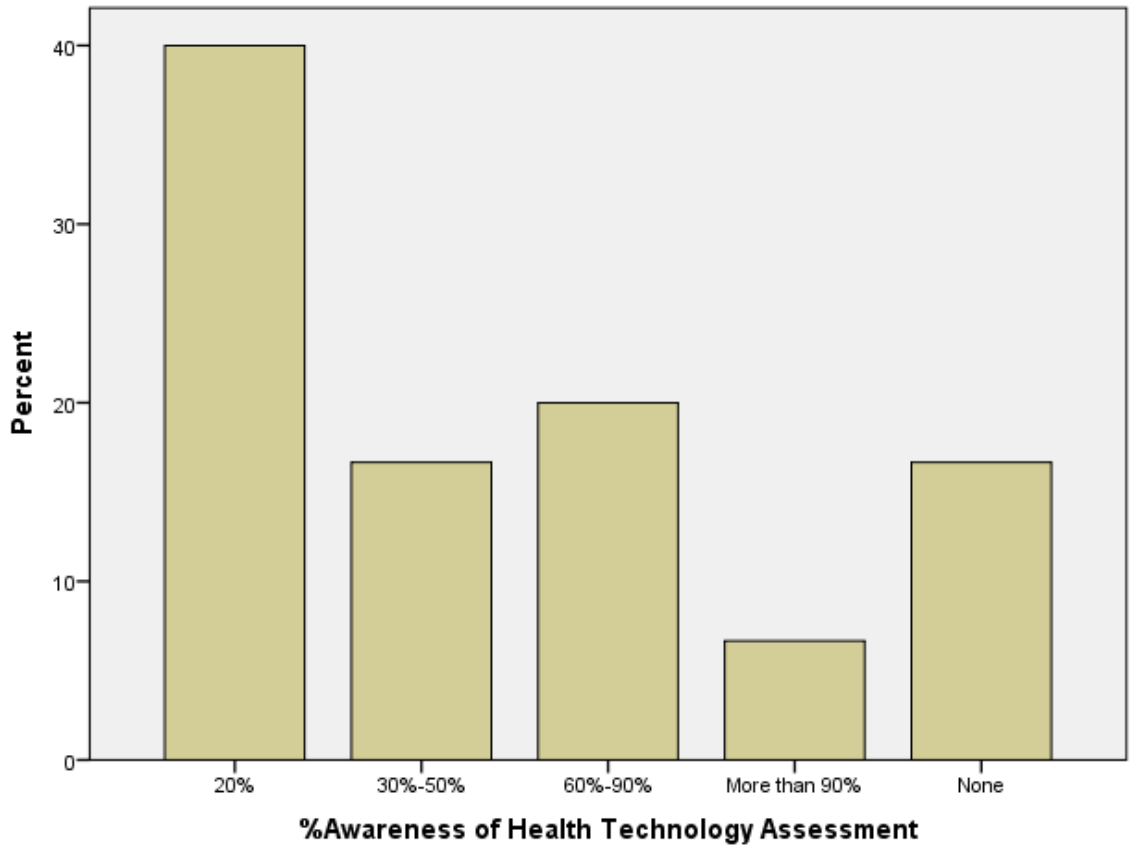


Figure 4-10: Awareness of Health Technology Assessment

Table (4-9) and figure (4-10) illustrate the lack in awareness of the concept of Health Technology Assessment whereas 40% percent goes for 20% of awareness.

Table 4-10: %Awareness of biomedical engineers at health team

%Awareness of BMEs role	Frequency	Percent
20%	6	20.0
30%-50%	5	16.7
60%-90%	11	36.7
More than 90%	3	10.0
None	5	16.7
Total	30	100.0

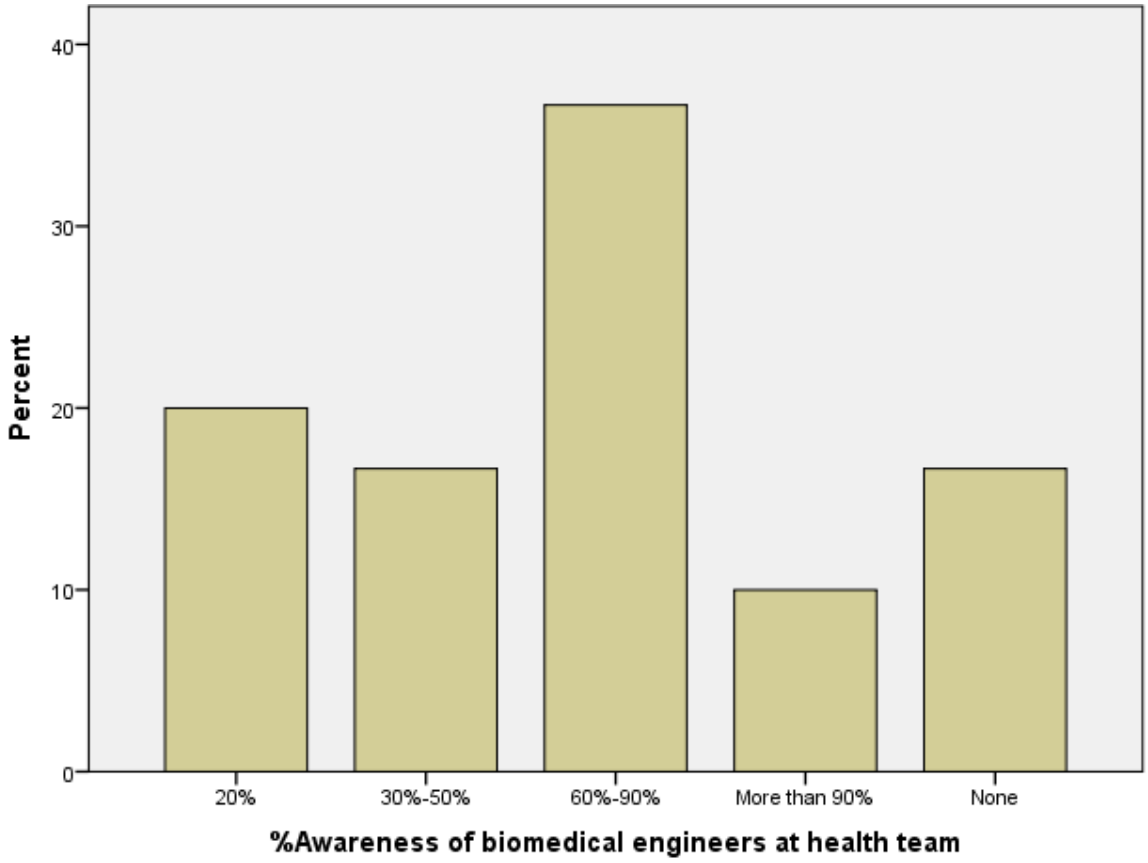


Figure **4-11: Awareness of biomedical engineers at health team**

Table (4-10) and figure (4-11) show that 36.7% of biomedical engineers know their important role at health team.

Table 4-11: BMEs Do All Maintenance types for medical equipment

Response	Frequency	Percent
Yes	25	83.3
None	5	16.7
Total	30	100.0

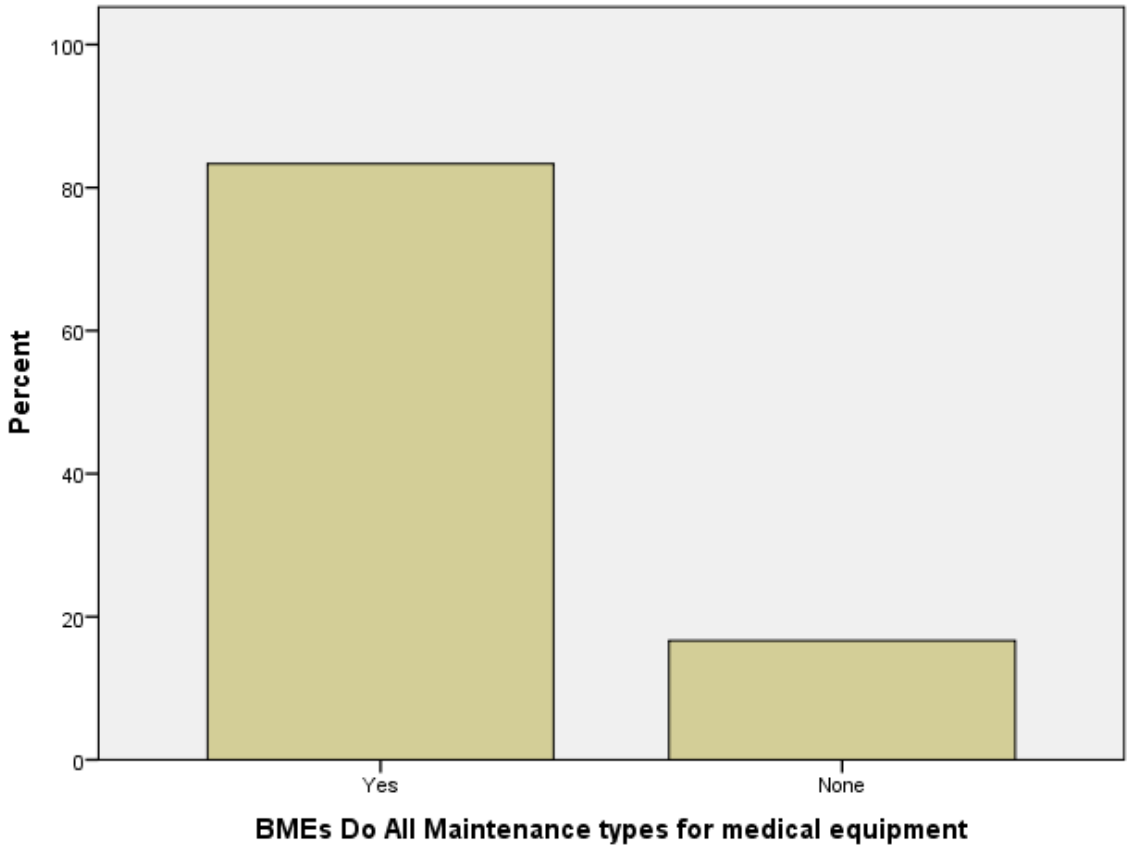


Figure 4-12: BMEs Do All Maintenance types for medical equipment

Table (4-11) and figure (4-12) reflect that no one except biomedical engineers can perform Inspection, preventive and Corrective maintenance for medical equipment at hospitals under study whereas 83.3% of them only biomedical engineers do All Maintenance types for medical equipment.

Table 4-12: BMEs Prepare and update Technical Specifications

Response	Frequency	Percent
Yes	19	63.3
No	6	20.0
None	5	16.7
Total	30	100.0

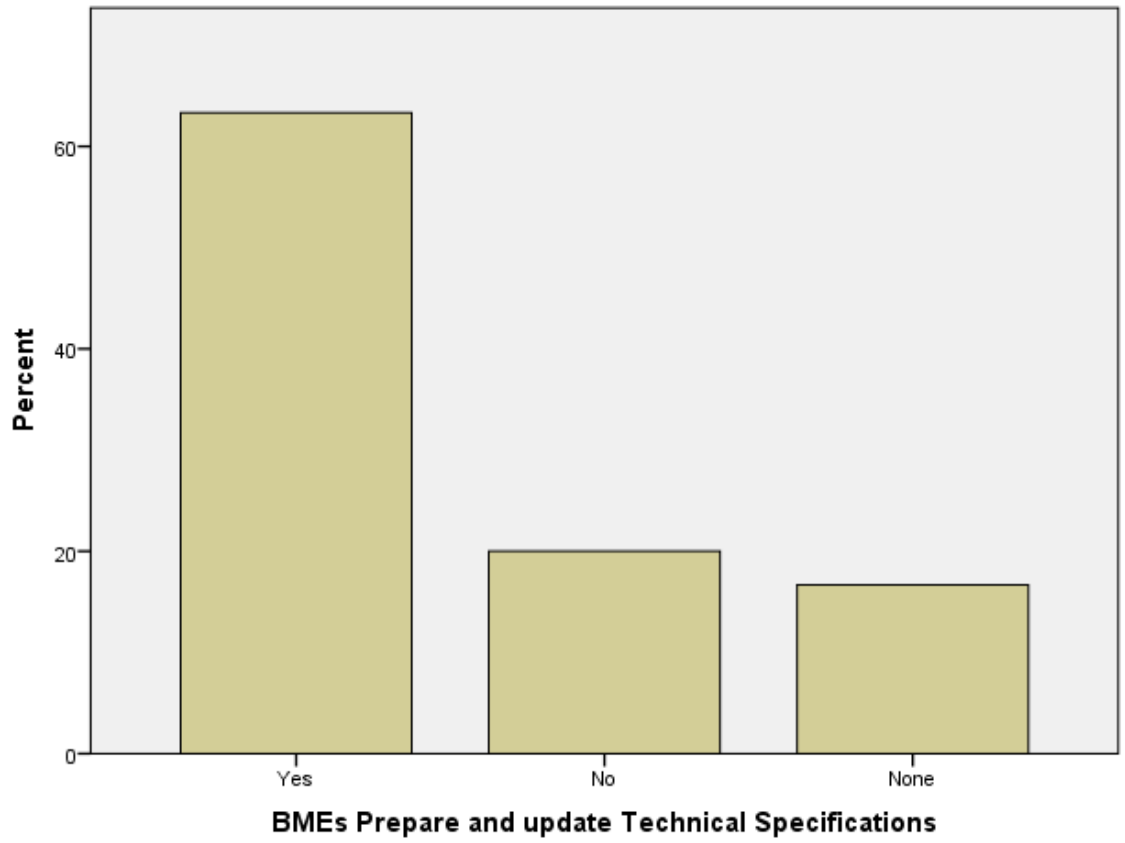


Figure 4-13: BMEs Prepare and update Technical Specifications

Table (4-12) and figure (4-13) explain that, only 63.3% of BMEs are included in preparing and updating technical specifications of medical equipment.

Table 4-13: BMEs provide studies for future extension

Response	Frequency	Percent
Yes	19	63.3
No	6	20.0
None	5	16.7
Total	30	100.0

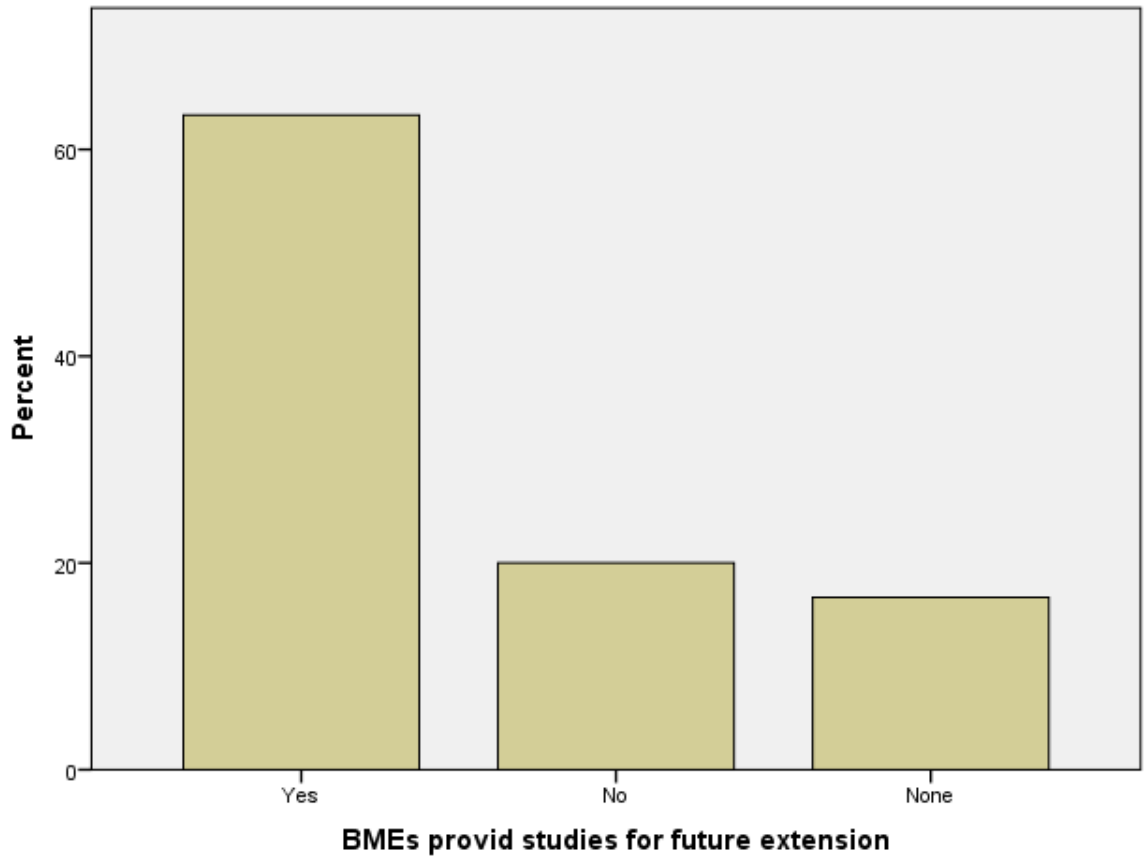


Figure 4-14: BMEs provide studies for future extension

Table (4-13) and figure (4-14) illustrate that, only 63.3% of BMEs are included in providing studies for future extension at hospitals in terms of medical equipment and buildings.

Table 4-14: BMEs train undergraduate & graduate students

Response	Frequency	Percent
Yes	22	73.3
No	3	10.0
None	5	16.7
Total	30	100.0

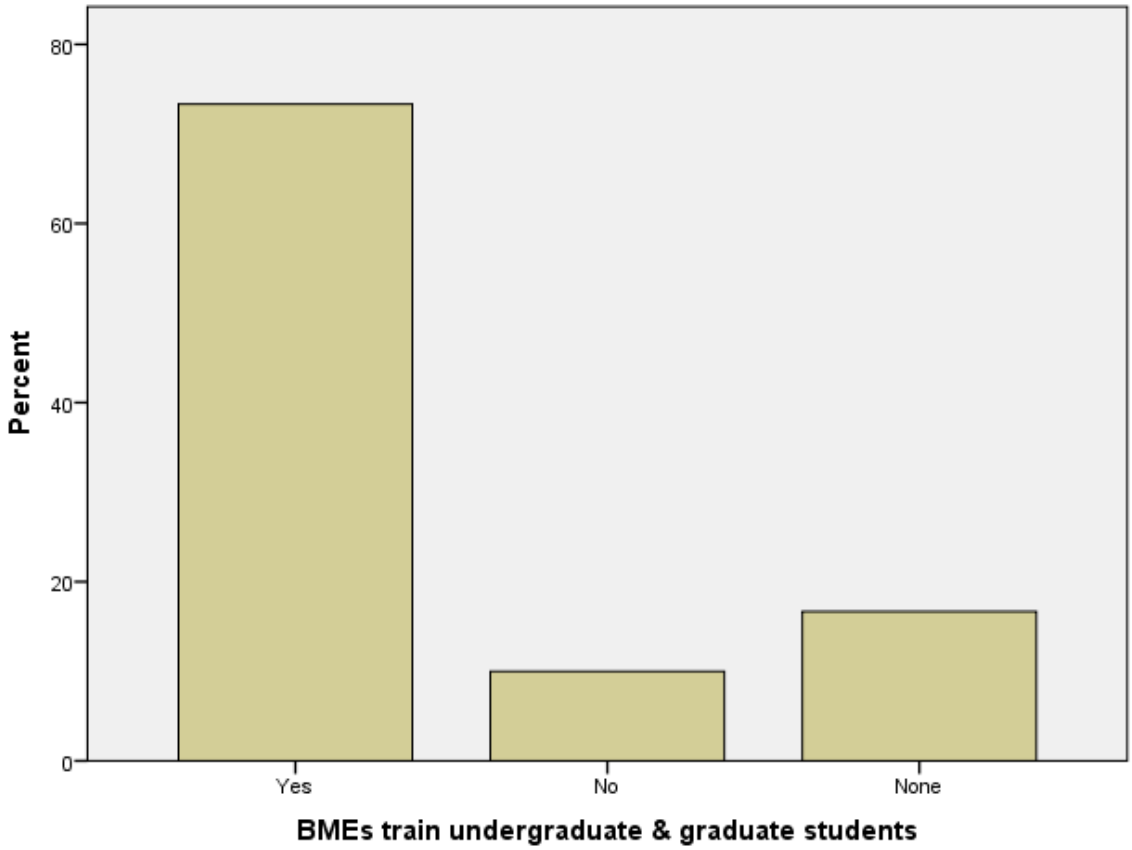


Figure 4-15: BMEs train undergraduate & graduate students

Table (4-14) and figure (4-15) show that, 73.3% of biomedical workshop perform the training for undergraduate & graduate students.

Table 4-15: BMEs train medical & technical staff

Response	Frequency	Percent
Yes	22	73.3
No	3	10.0
None	5	16.7
Total	30	100.0

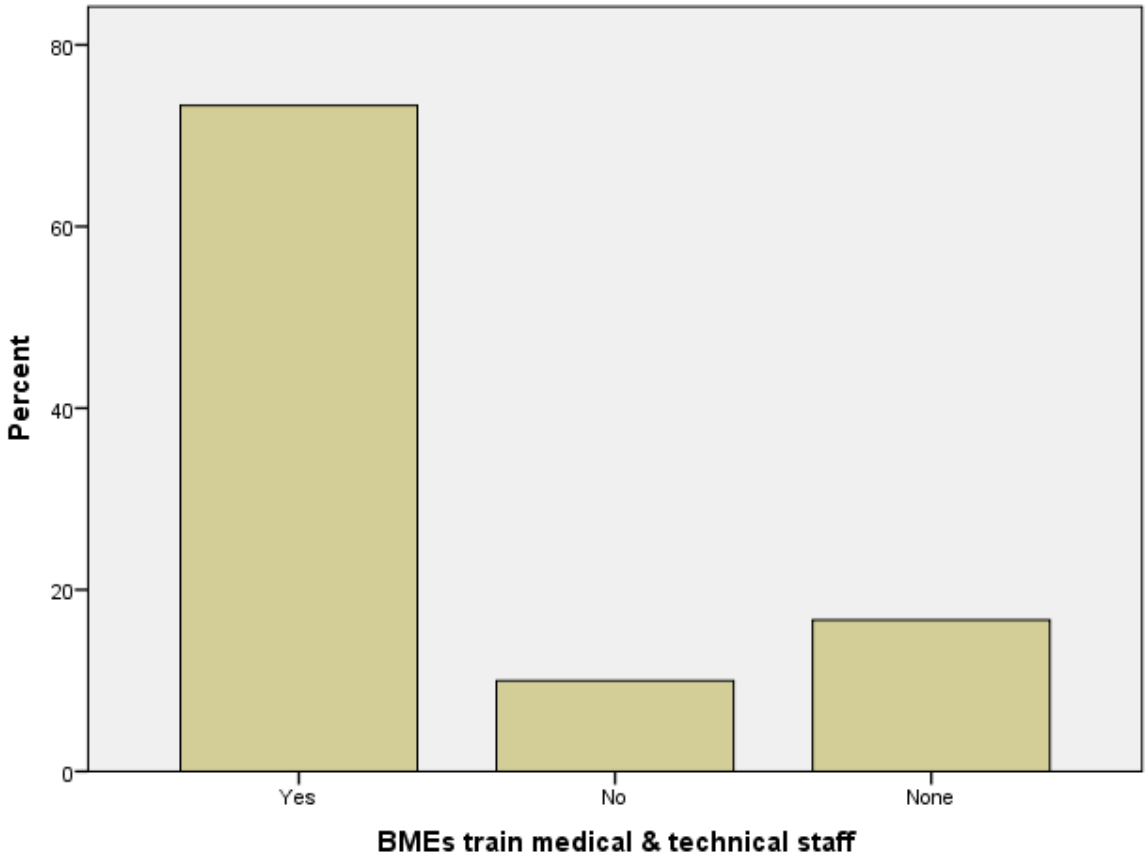


Figure 4-16: BMEs train medical & technical staff

Table (4-15) and figure (4-16) describe that 73.3% of biomedical workshop perform the training for medical and technical staff.

Table 4-16: BMEs carry out purchase orders of equipment & its spare parts

Response	Frequency	Percent
Yes	23	76.7
No	2	6.7
None	5	16.7
Total	30	100.0

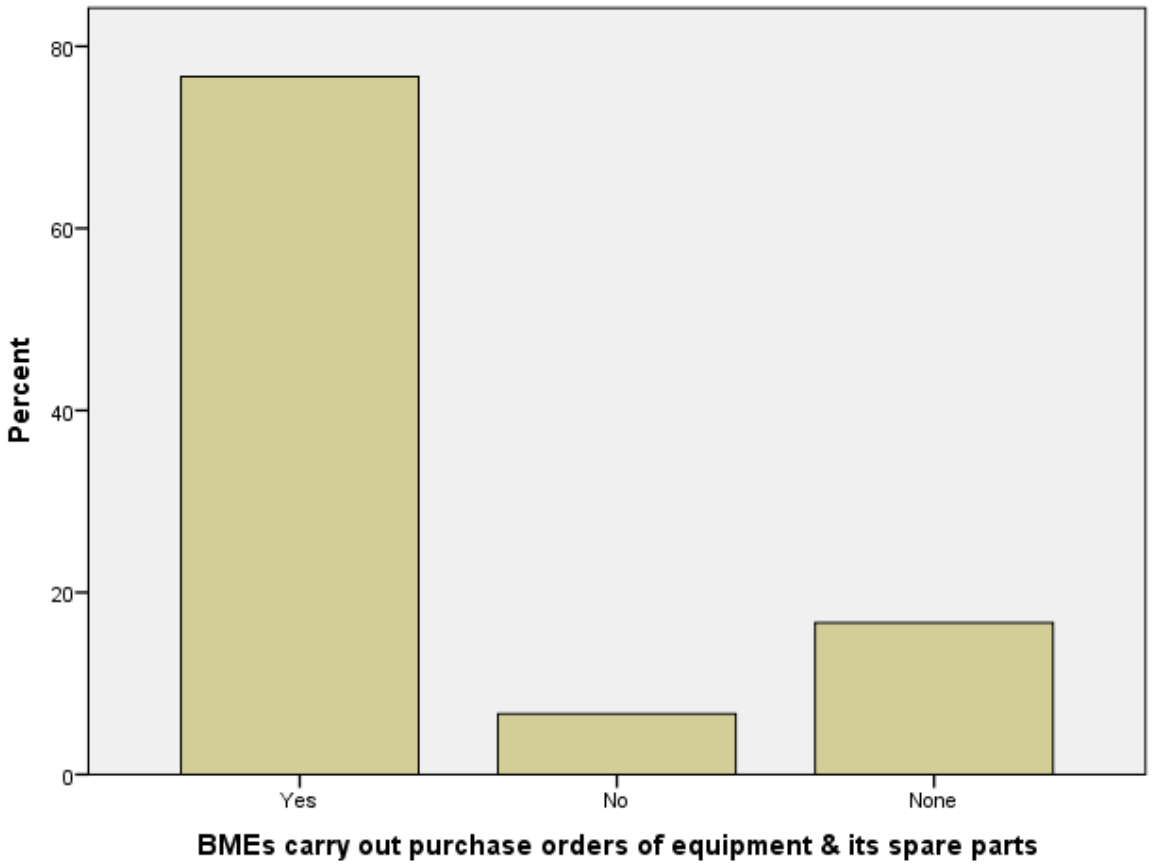


Figure 4-17: BMEs carry out purchase orders of equipment & its spare parts

Table (4-16) and figure (4-17) above show that 76.6 of BMEs at hospitals are included in the purchasing process of medical equipment and its spare parts.

Table 4-17: BMEs prepare and follow up approvals and purchase decisions

Response	Frequency	Percent
Yes	21	70.0
No	4	13.3
None	5	16.7
Total	30	100.0

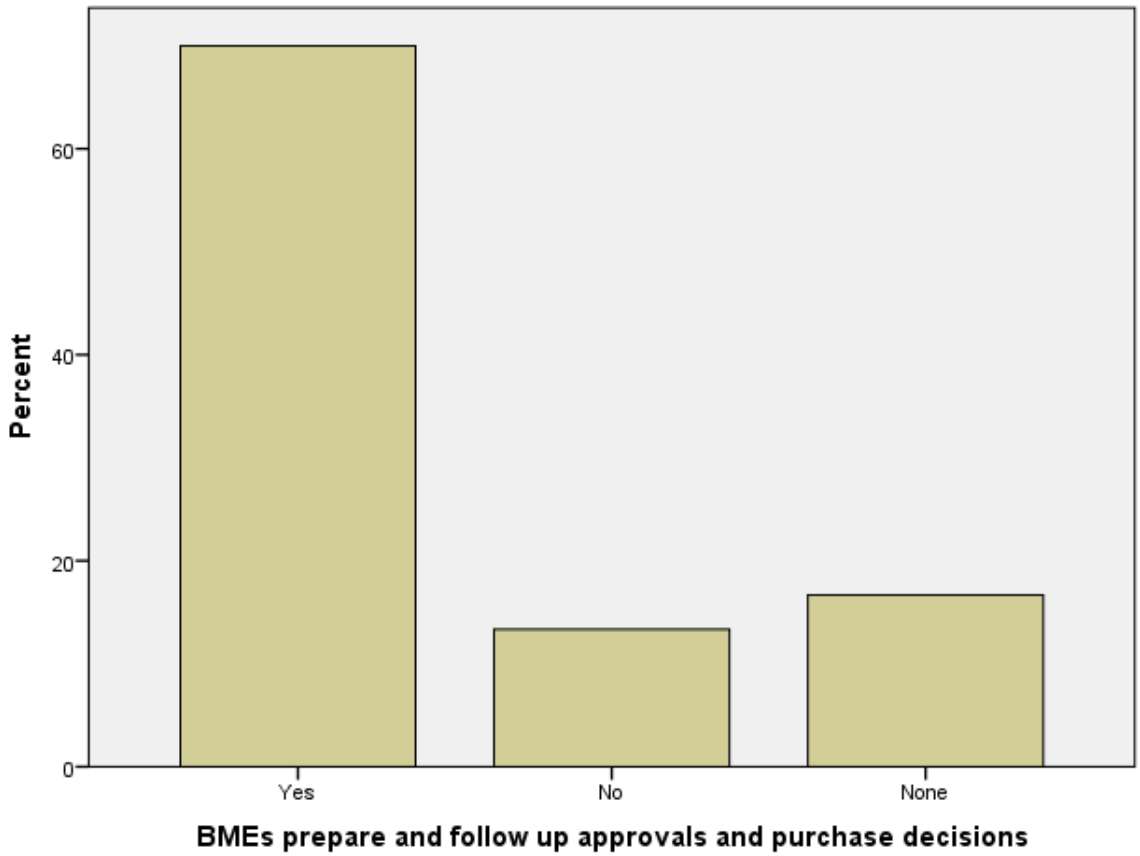


Figure 4-18: BMEs prepare and follow up approvals and purchase decisions

Table (4-17) and figure (4-18) above show that 70.0 of BMEs at hospitals prepare and follow up approvals and purchase decisions

Table 4-18: BMEs manage financial guarantees related to purchase processes

Response	Frequency	Percent
Yes	19	63.3
No	6	20.0
None	5	16.7
Total	30	100.0

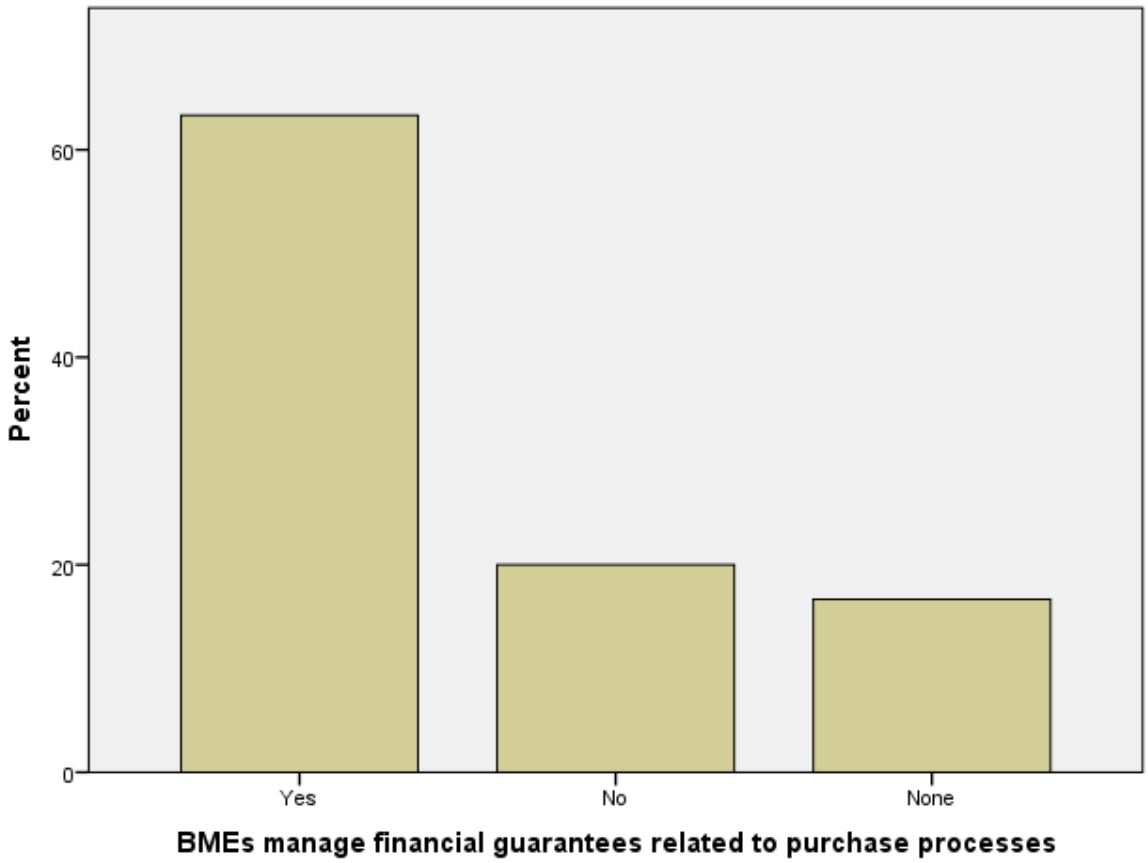


Figure 4-19: BMEs manage financial guarantees related to purchase processes

Table (4-18) and figure (4-19) illustrate that 63.3% of BMEs BMEs manage financial guarantees related to purchase processes.

Table 4-19: BMEs manage central stores with regard to equipment issues

Response	Frequency	Percent
Yes	24	80.0
No	1	3.3
None	5	16.7
Total	30	100.0

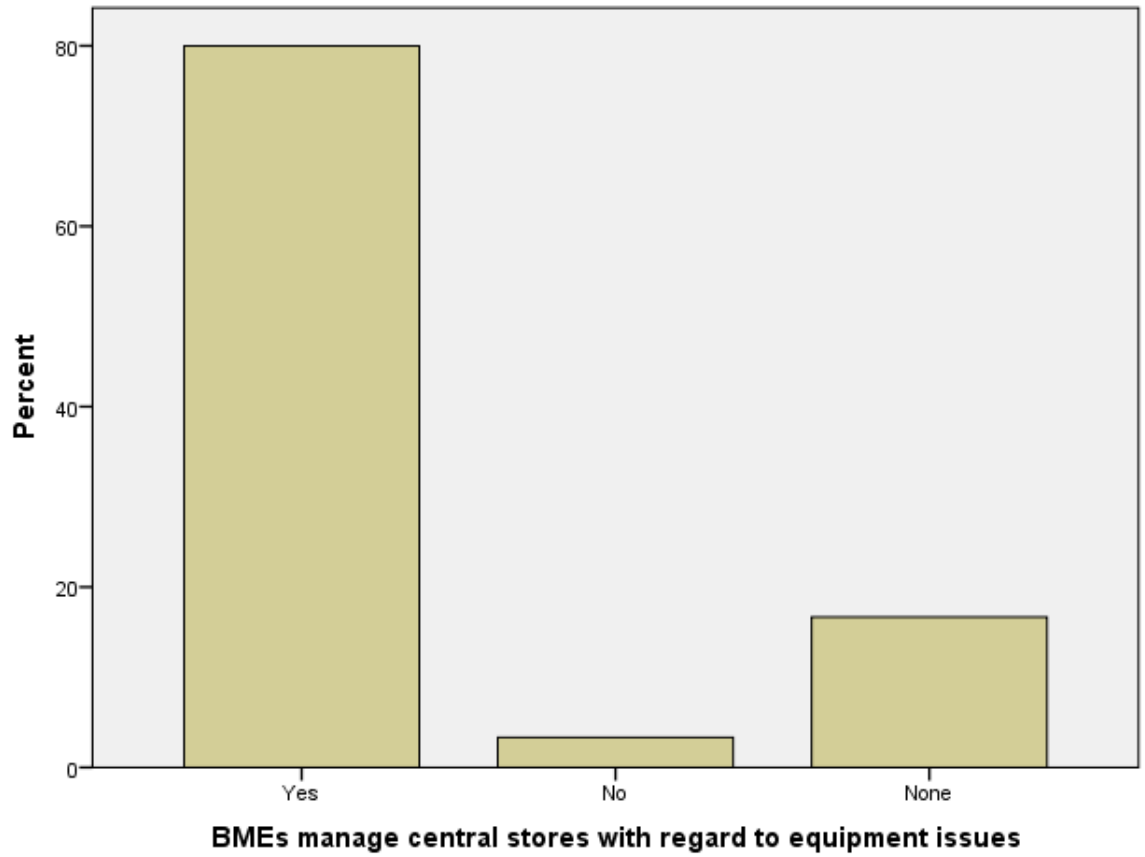


Figure 4-20: BMEs manage central stores with regard to equipment issues

Table (4-19) and figure (4-20) describe that 80% of BMEs Manage the central stores (reception, storage and dispense spare parts and medical equipment accessories).

Table 4-20: BMEs keep information records on vendors & evaluate their performance

Response	Frequency	Percent
Yes	19	63.3
No	6	20.0
None	5	16.7
Total	30	100.0

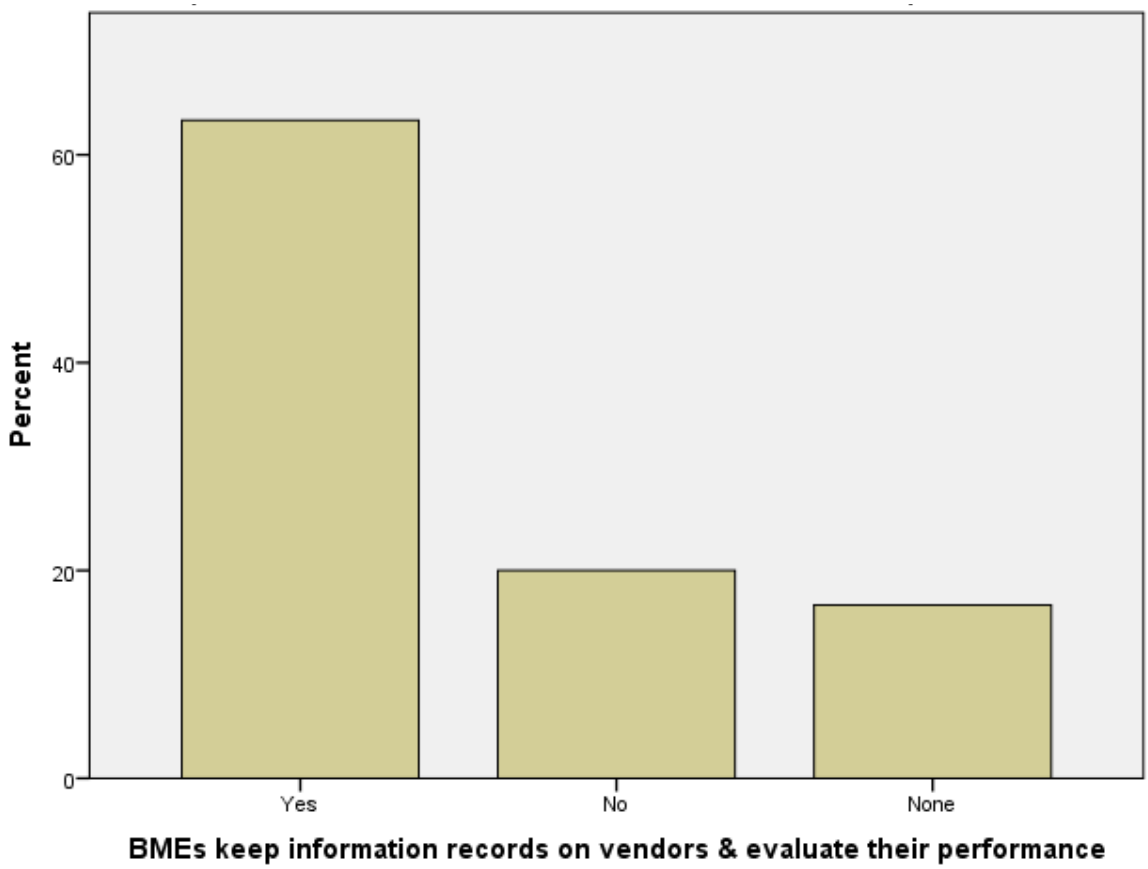


Figure 4-21: BMEs keep information records on vendors & evaluate their performance

Table (4-20) and figure (4-21) shows that 63.3 of BMEs Keep information records on vendors and evaluate their performance.

Table 4-21: Do you have job description of BMEs at your hospital

Response	Frequency	Percent
Yes	11	36.7
No	14	46.7
None	5	16.7
Total	30	100.0

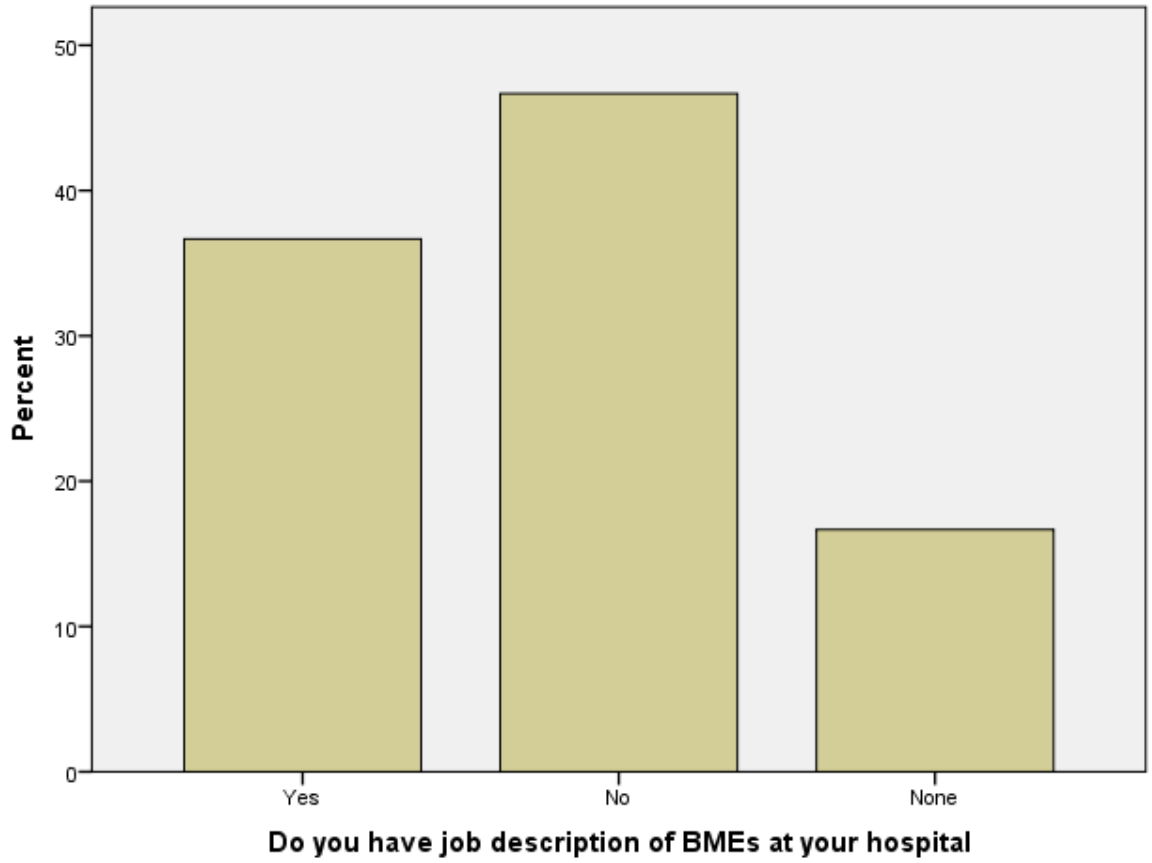


Figure 4-22: Do you have job description of BMEs at your hospital

Table (4-21) and figure (4-22) shows that 36.7% of BMEs have no job description of biomedical engineers at hospitals.

Table 4-22: % How much does your current WS match the ideal one

%Matching	Frequency	Percent
20%	14	46.7
30%-50%	8	26.7
60%-90%	2	6.7
More than 90%	1	3.3
None	5	16.7
Total	30	100.0

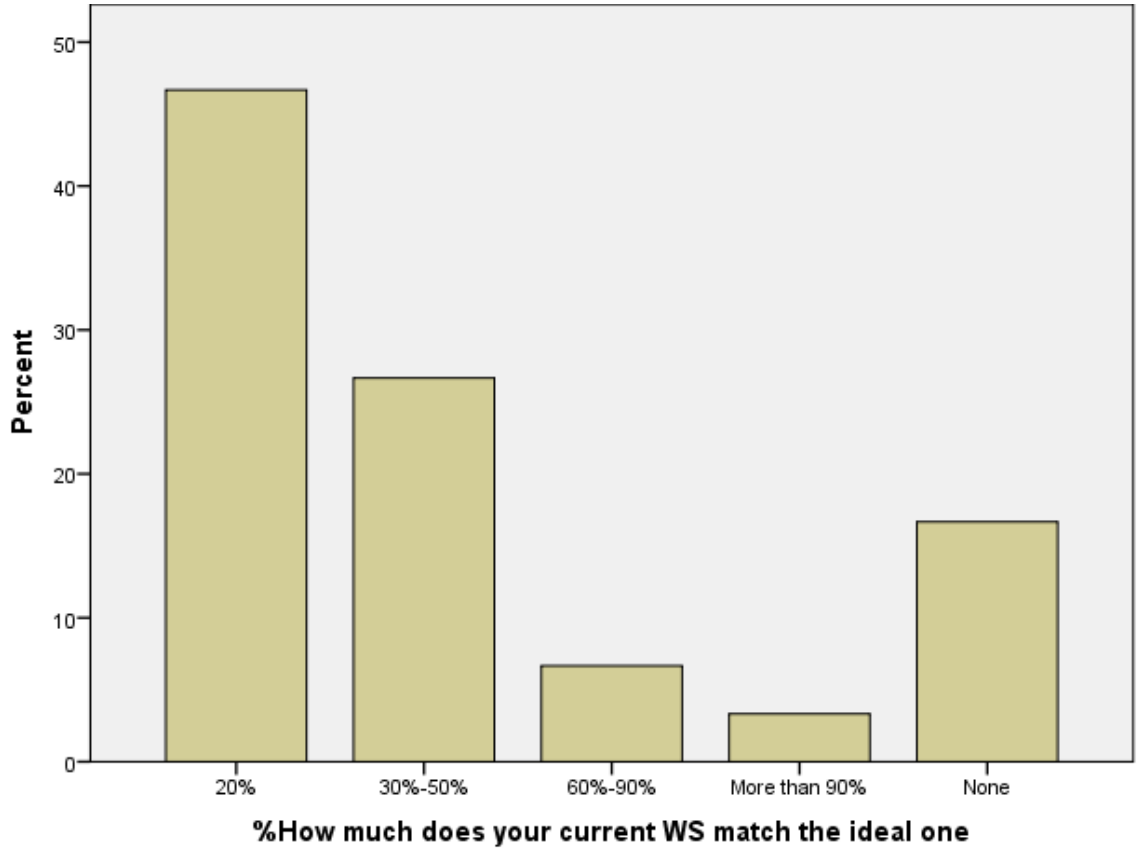


Figure 4-23: % How much does your current WS match the ideal one

Table (4-22) and figure (4-23) show that46.7% of the current biomedical WSs don't match the ideal ones.

Table 4-23: Do you have in house service contract

Response	Frequency	Percent
Yes	7	23.3
No	18	60.0
None	5	16.7
Total	30	100.0

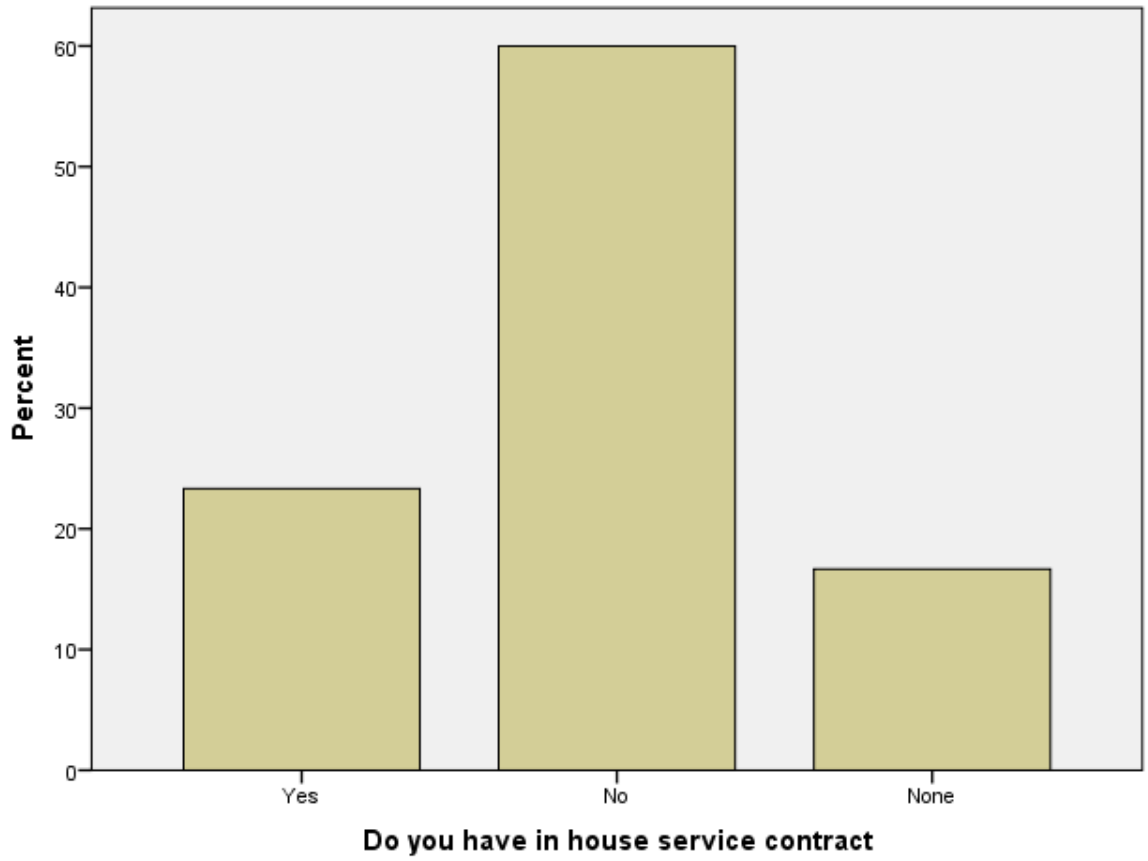


Figure 4-24: Do you have in house service contract

Table (4-23) and figure (4-24) show that 60% of hospitals doesn't have in house service contract.

Table 4-24: Do you have local agents' service contract

Response	Frequency	Percent
Yes	23	76.7
No	2	6.7
None	5	16.7
Total	30	100.0

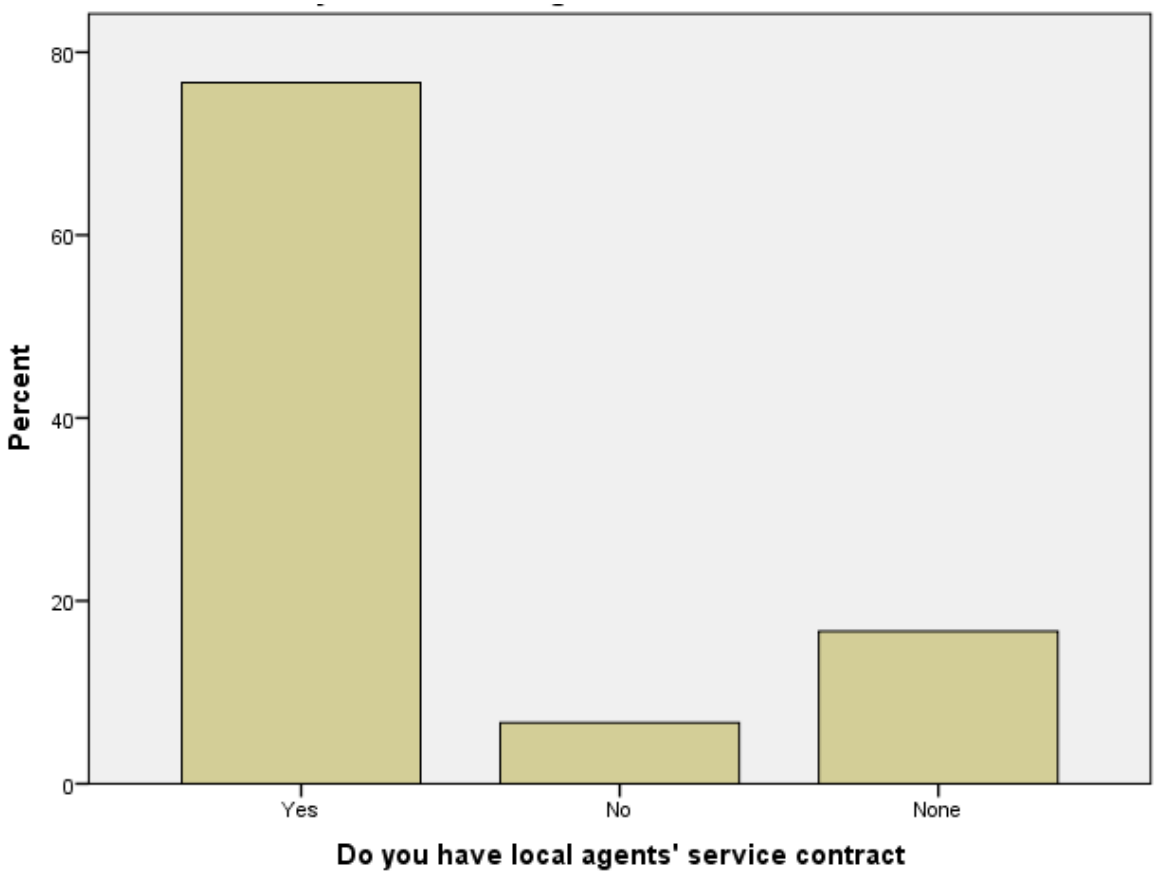


Figure 4-25: Do you have local agents' service contract

Table (4-24) and figure (4-25) show that 76.7% of hospitals have local agents' service contract.

Table 4-25: BMWS supervise maintenance contract

Response	Frequency	Percent
Yes	21	70.0
No	4	13.3
None	5	16.7
Total	30	100.0

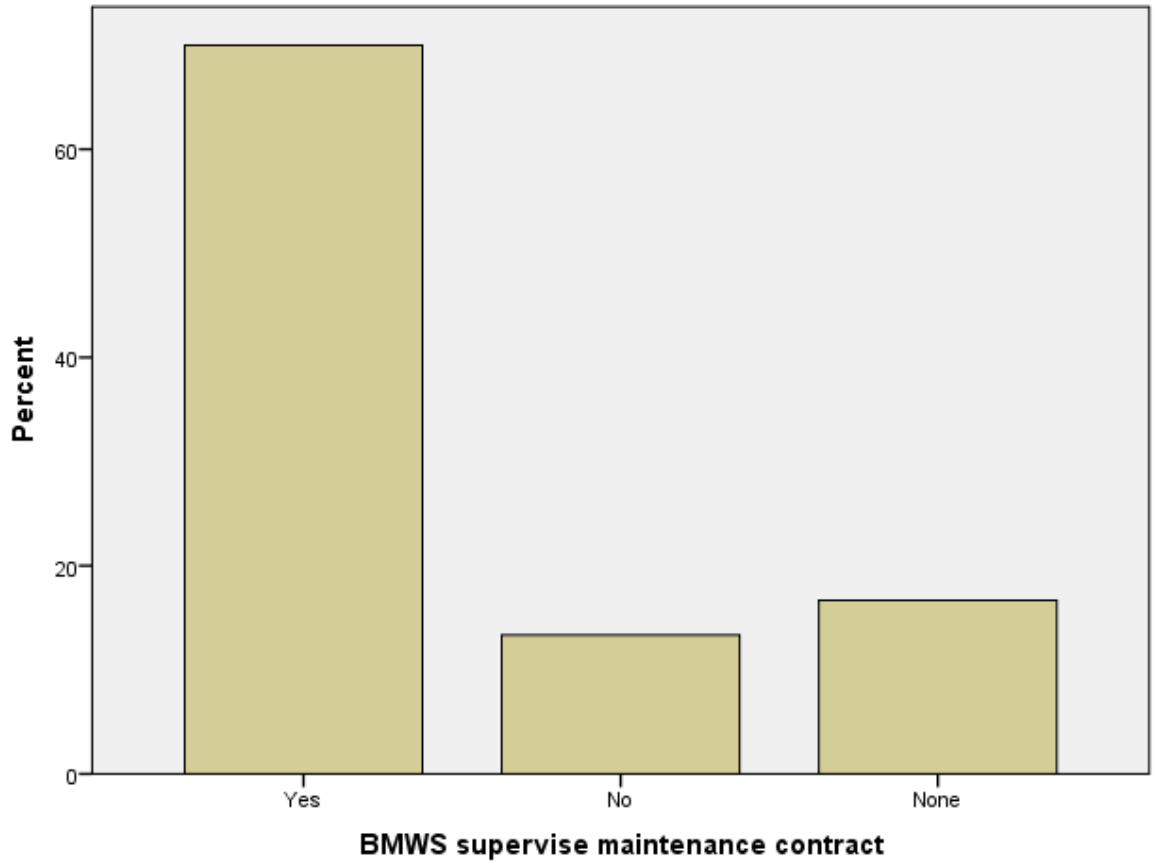


Figure 4-26: BMWS supervise maintenance contract

Table (4-25) and figure (4-26) show that 70% of BMWS supervise maintenance contract.

Table 4-26: BMWS supervise maintenance of equipment in warranty period

Response	Frequency	Percent
Yes	22	73.3
No	3	10.0
None	5	16.7
Total	30	100.0

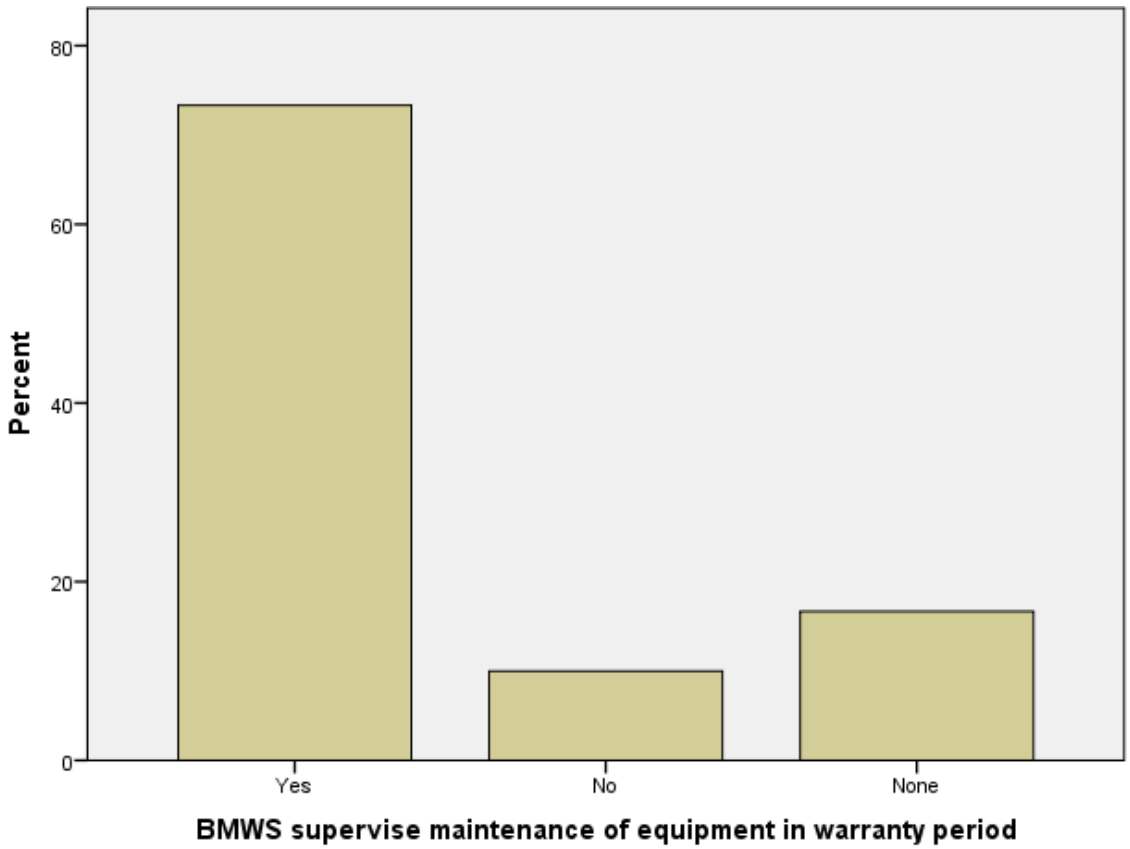


Figure 4-27: BMWS supervise maintenance of equipment in warranty period

Table (4-26) and figure (4-27) show that 73.3% of BMWS supervise maintenance of equipment in warranty period.

Table 4-27: BMWS supervise & follow up reception of medical equipment

Response	Frequency	Percent
Yes	22	73.3
No	3	10.0
None	5	16.7
Total	30	100.0

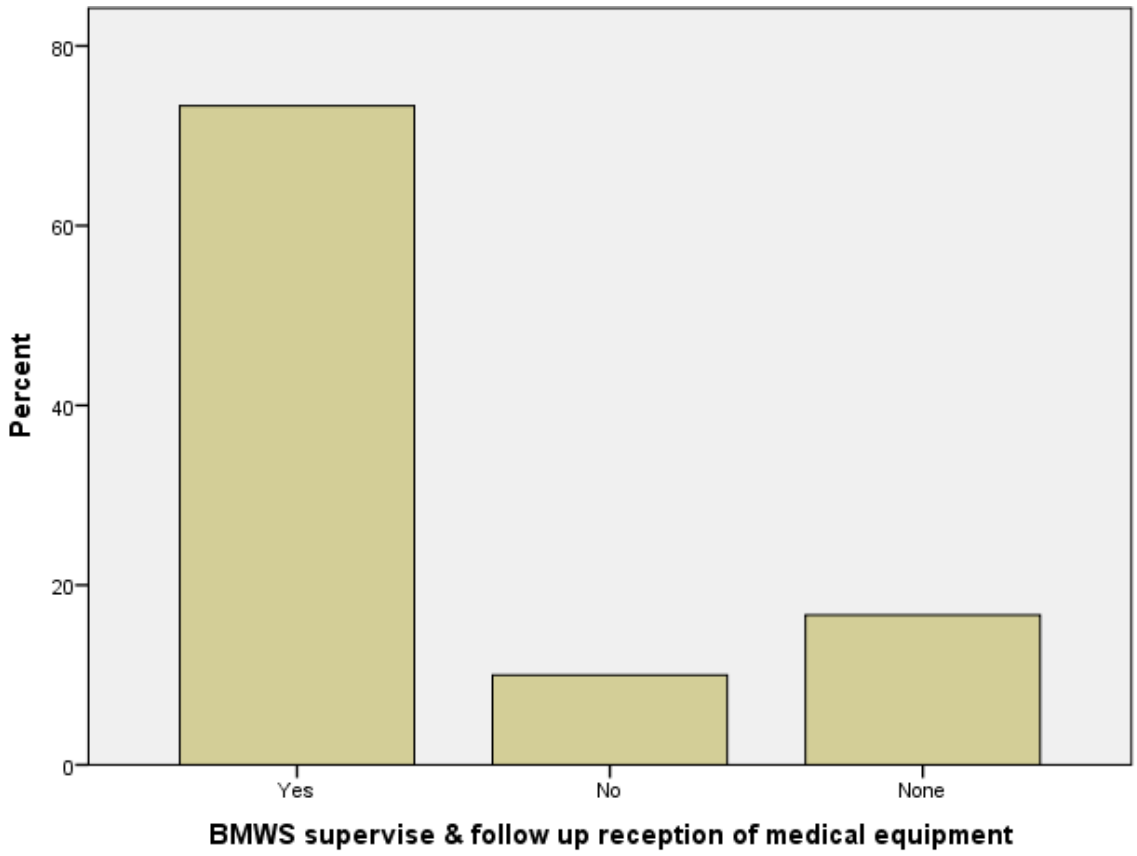


Figure 4-28: BMWS supervise & follow up reception of medical equipment

Table (4-27) and figure (4-28) show that 73.3% of BMWS supervise & follow up reception of medical equipment

Table 4-28: Do you have paper documentation at BMWS

Response	Frequency	Percent
Yes	25	83.3
None	5	16.7
Total	30	100.0

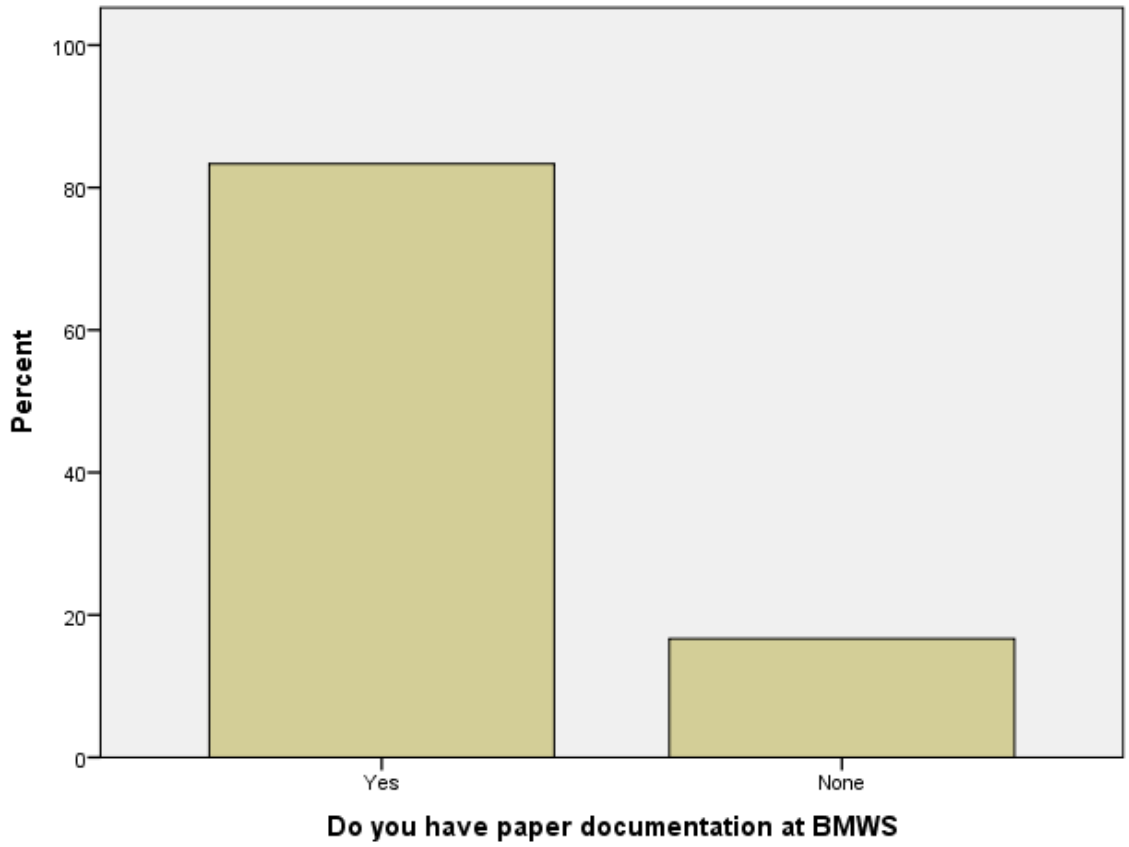


Figure 4-29: Do you have paper documentation at BMWS

Table (4-28) and figure (4-29) show that 83.3% of BMWS have paper documentation.

Table 4-29: Do you have Computerized Documentation at BMWS

Response	Frequency	Percent
Yes	18	60.0
No	7	23.3
None	5	16.7
Total	30	100.0

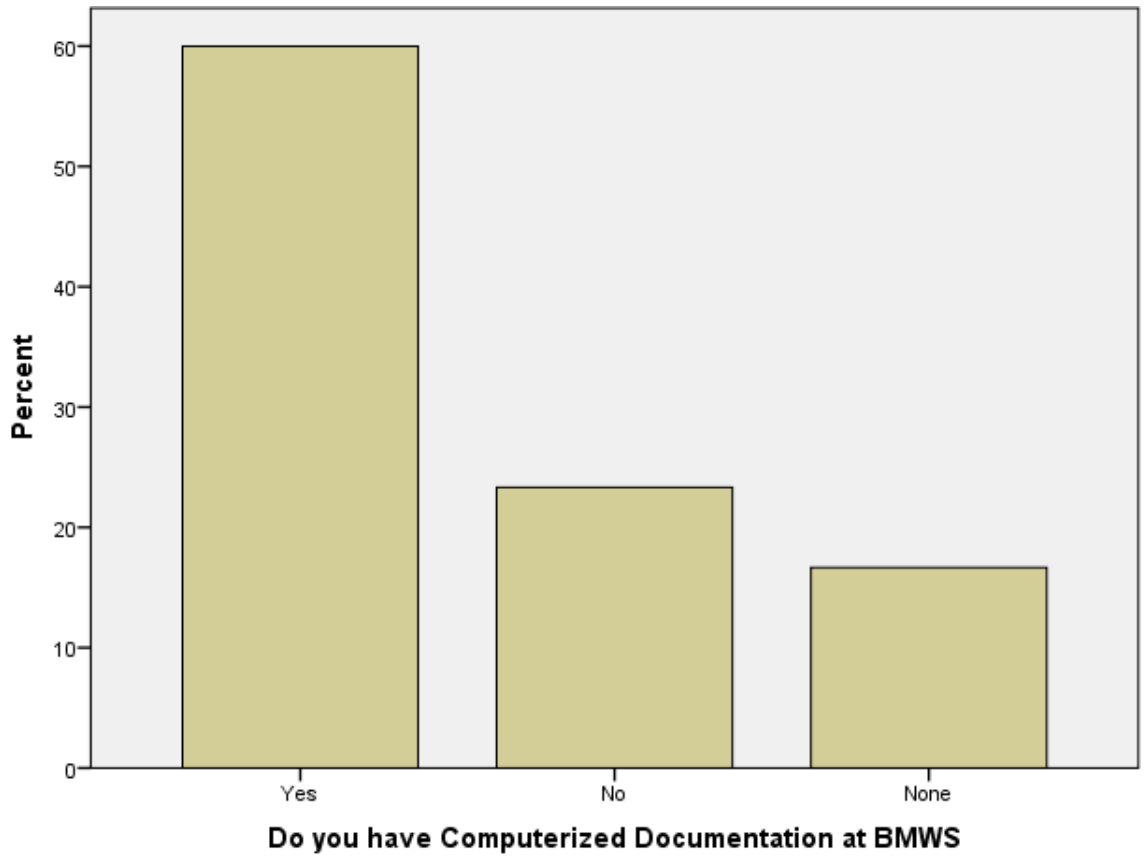


Figure 4-30: Do you have Computerized Documentation at BMWS

Table (4-29) and figure (4-30) show that 60% of BMWS have Computerized Documentation.

As it is shown in the tables and charts above the frequencies and the percentages that acquired from the answers of respondents which reflect the real situation of how much they applying the concept of Ideal workshop in their hospitals.

Chapter Five

Actual workshops Vs typical workshops

5.1.1 Three samples of hospitals have capacity in beds [100<200 and more than 200]:

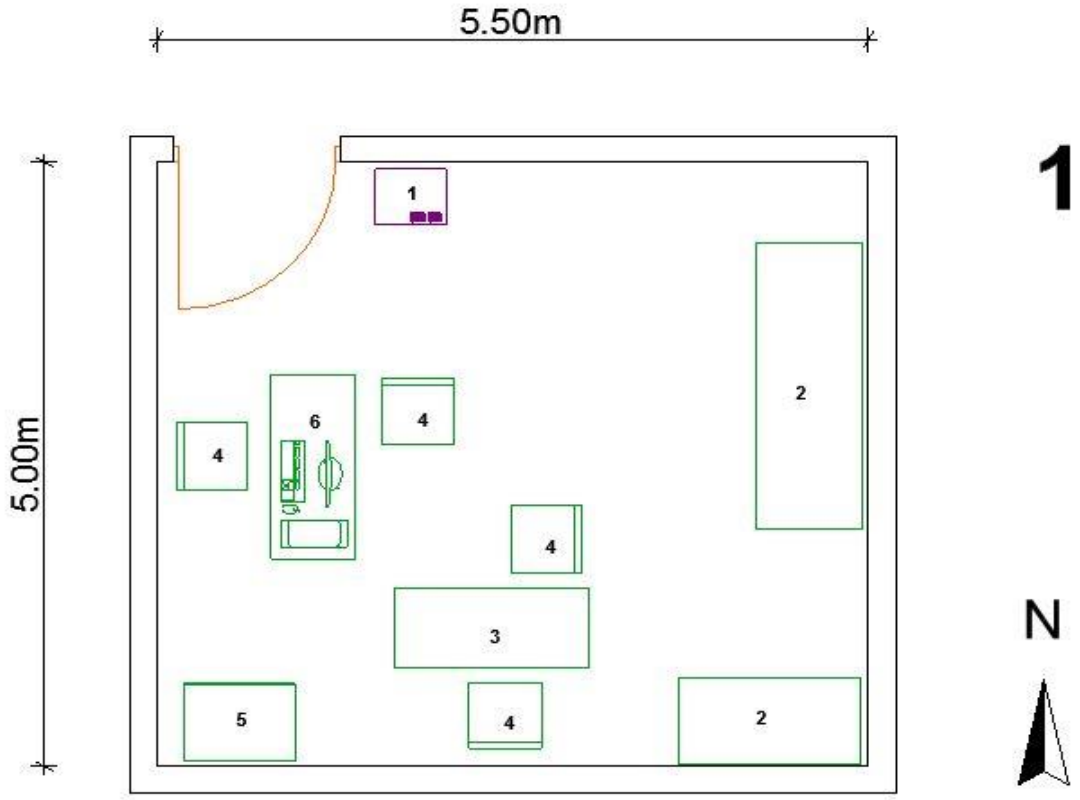


Figure 5-1: sample one

1: A water cooler.

2: Benches for repairing equipment.

3: An office desk

4: Chairs.

5: A cupboard contains electronics' repair tools, spare parts, manuals and documents' file.

6: An office desk with computer.

Figure (5-1) above illustrate the lack of important things which this workshop faces whereas the actual area is (5m×5.5m) while the ideal area should be (9m×12m).also there are no mechanical work area, carpenter's work area, welding area, store room and changing room.

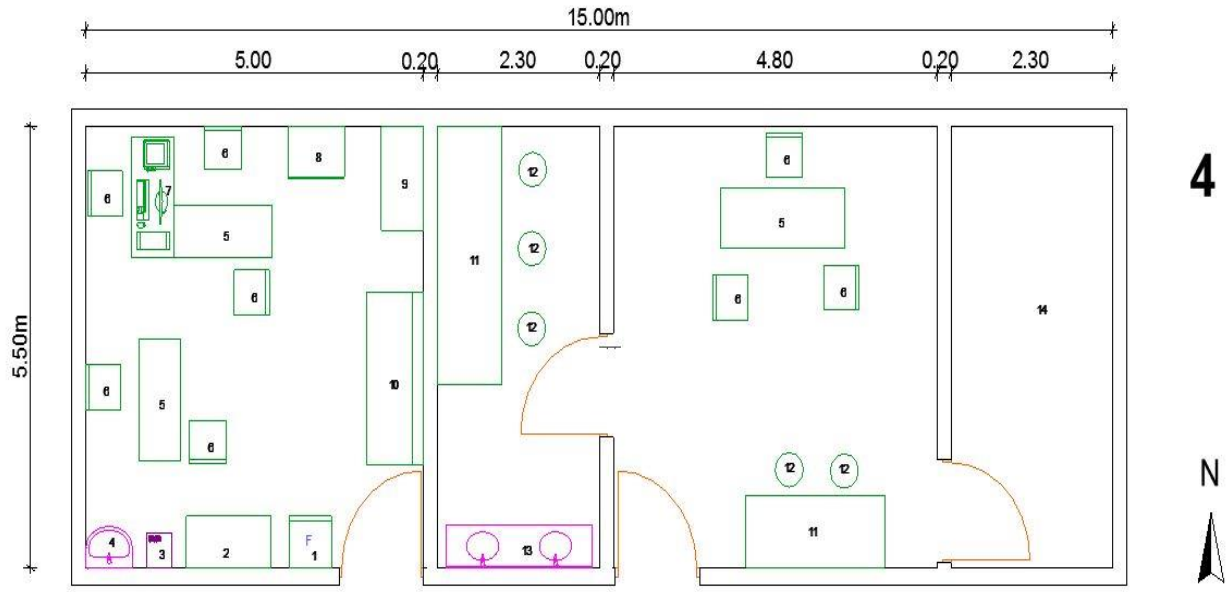


Figure 5-2: sample four

1: A refrigerator.

2: A cupboard contains repaired equipment.

3: A water cooler.

4: A basin

5: office desks.

6: Chairs.

7: An office desk with computer and printer.

8: A cupboard contains manuals and documents' file.

9: A cupboard contains electronics' repair tools and spare parts.

10: A sofa.

11: Benches for repairing equipment.

12: Stools.

13: A washbasin.

14: A store for scrap of medical equipment.

Figure (5-2) above shows the good layout of this workshop to high extend whereas the actual area is (5.5m×15m) while the ideal area should be (9m×12m).but there are no mechanical work area, carpenter's work area and welding area

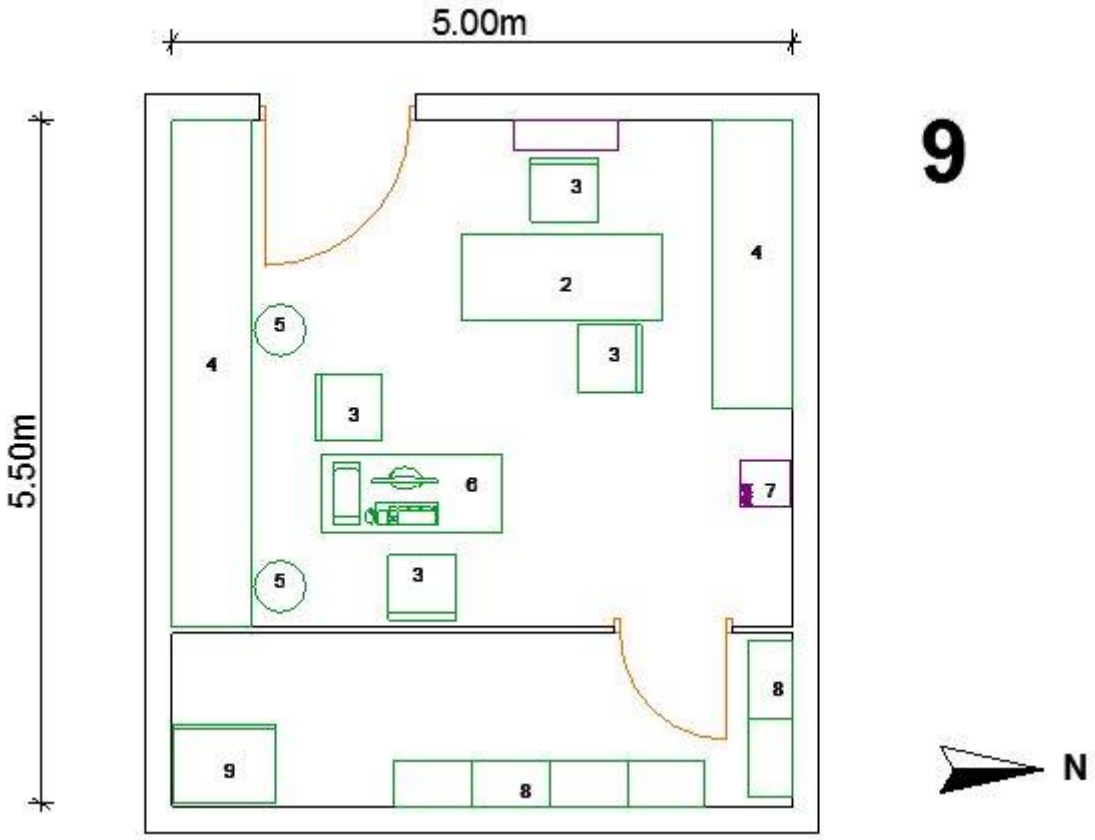


Figure 5-3: sample nine

1: An air conditioning.

2: An office desk.

3: Chairs.

4: Benches for repairing equipment.

5: Stools.

6: An office desk with computer.

7: A water cooler.

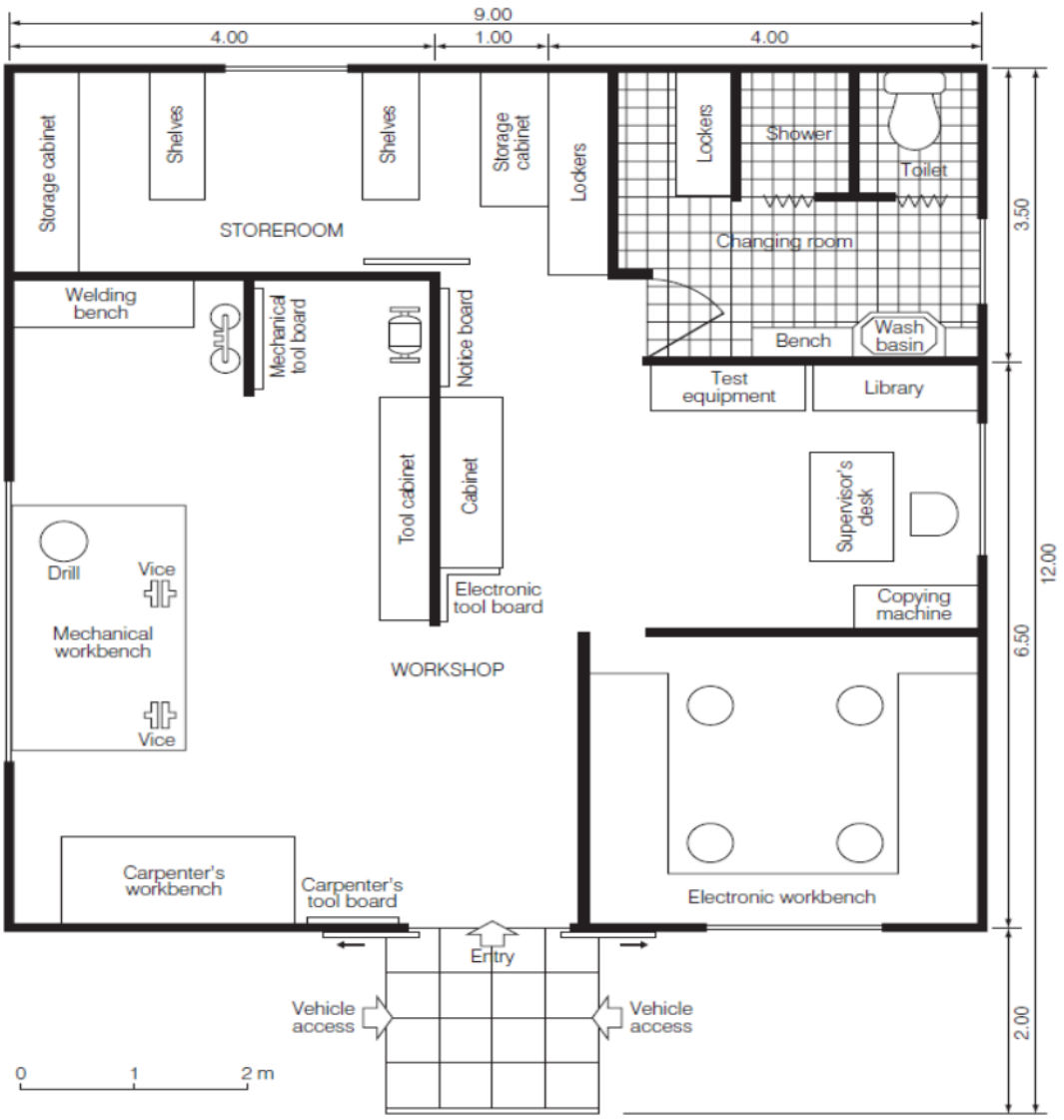
8: Shelves contain out of use equipment.

9: A cupboard contains electronics' repair tools, spare parts and documents' file.

6: An office desk with computer.

Figure (5-3) above illustrates the poorly laid out of this workshop faces whereas the actual area is (5m×5.5m) while the ideal area should be (9m×12m).also there are no mechanical work area, carpenter's work area, welding area, manuals cabinets and changing room.

5.1.2 A Typical Layout for a Workshop of a 100-Bed Hospital:



Source: WHO Regional Office for the Western Pacific, 1996, 'District hospitals: guidelines for development', 2nd edition, Western Pacific Series No.4, WHO Regional Publications, Manila, Philippines

Figure 5-4: A Typical Layout for a Workshop of a 100-Bed Hospital

5.2.1Three samples of hospitals have capacity in beds [50<100 and less than 50]:

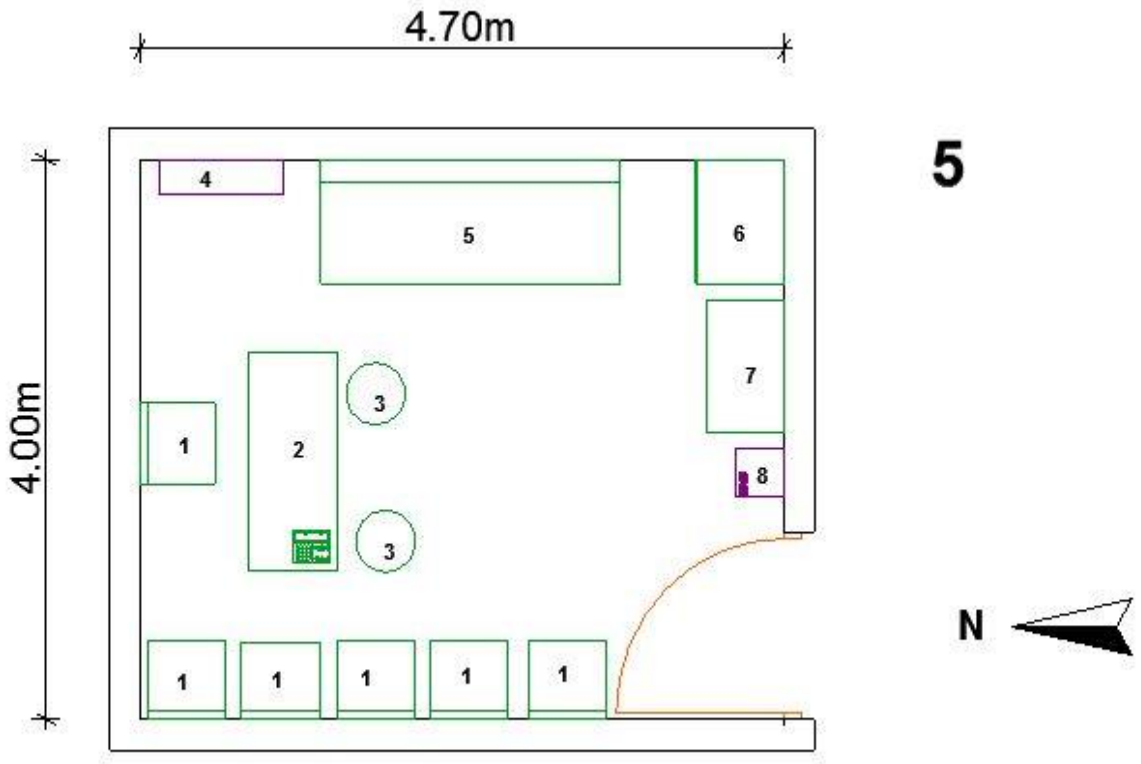


Figure 5-5: sample five

1: Chairs.

2: An office desk with telephone.

3: Stools.

4: An air conditioning.

5: A sofa.

6: A cupboard contains electronics' repair tools, manuals and documents' file.

7: Drawers for Fuses' spare parts.

8: A water cooler.

Figure (5-5) above shows the lack of important things which this workshop faces whereas the actual area is (4m×4.7m) while the ideal area should be (7m×10m).also there are no mechanical work area, carpenter's work area, welding area, store room and changing room.

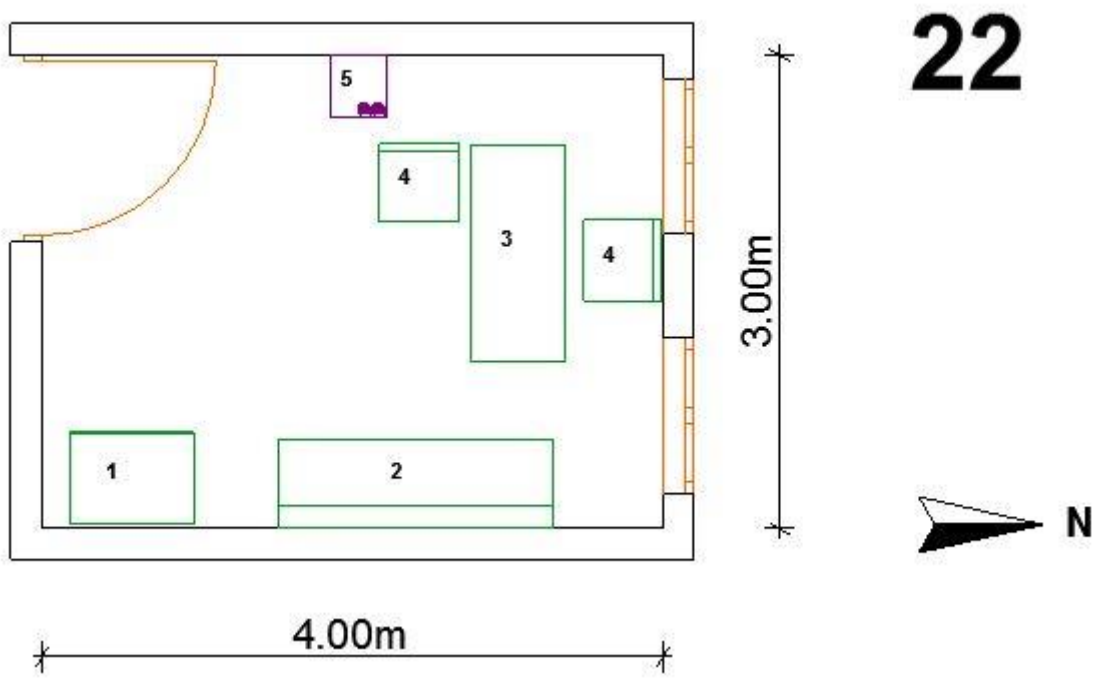


Figure 5-6: sample twenty-two

1: A cupboard contains electronics' repair tools, spare parts, manuals and documents' file.

2: A sofa.

3: An office desk.

4: Chairs.

5: A water cooler.

Figure (5-6) above illustrates the poorly laid out of this workshop faces whereas the actual area is (3m×4m) while the ideal area should be (7m×10m).also there are no electronic work area mechanical work area, carpenter's work area, welding area, store room and changing room.

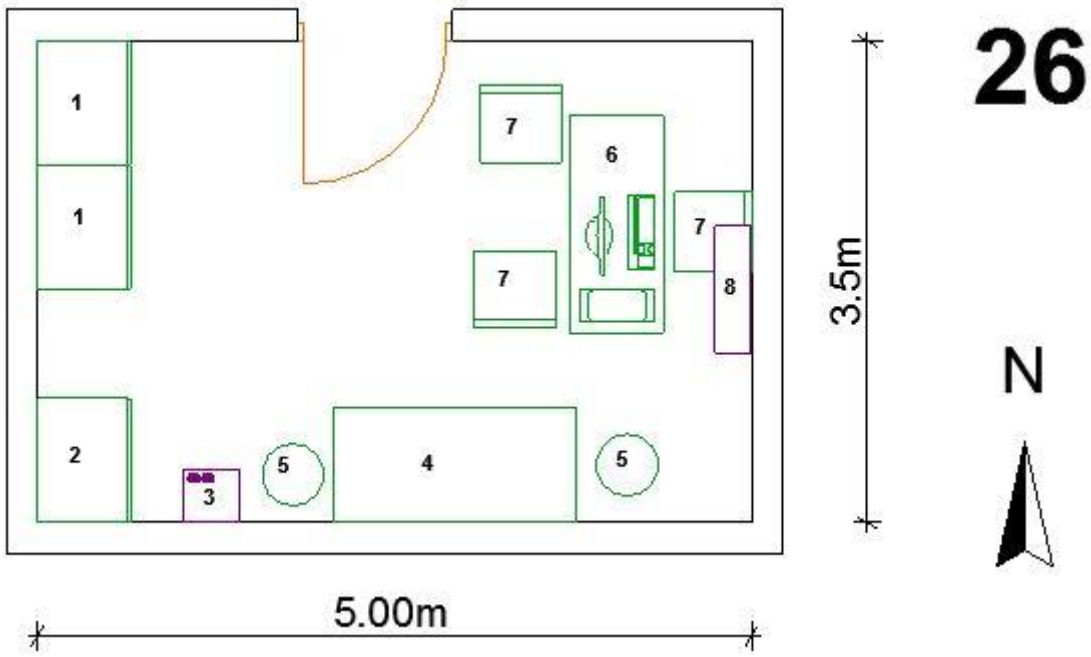


Figure 5-7: sample twenty-six

1: Cupboards contain spare parts.

2: A cupboard contains electronics' repair tools, manuals and documents' file.

3: A water cooler.

4: A bench for repairing equipment.

5: Stools.

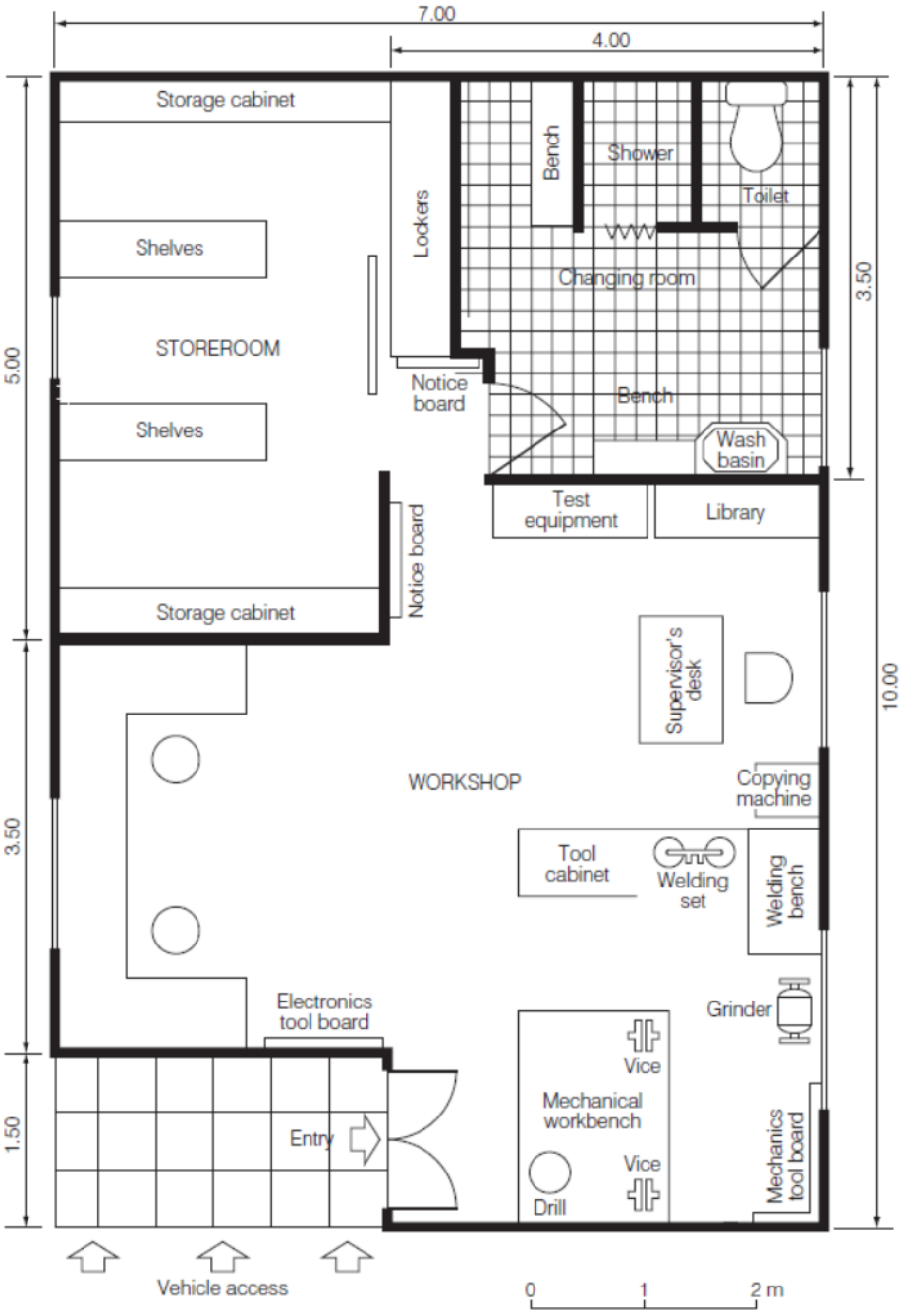
6: An office desk with computer.

7: Chairs.

8: An air conditioning.

Figure (5-7) above shows the lack of important things which this workshop faces whereas the actual area is (3.5m×5m) while the ideal area should be (7m×10m).also there are no mechanical work area, carpenter's work area, welding area, store room and changing room.

5.2.2 A Typical Layout for a Workshop of a 50-Bed Hospital:



Source: WHO Regional Office for the Western Pacific, 1996, 'District hospitals: guidelines for development', 2nd edition, Western Pacific Series No.4, WHO Regional Publications, Manila, Philippines

Figure 5-8: A Typical Layout for a Workshop of a 50-Bed Hospital

Chapter Six

Discussion

6.1 Discussion:

In all hospitals under the study the workshops are not typical workshops for biomedical engineering department depending on operating capacity of these hospitals in beds. Furthermore there is 20 percent of these hospitals have no workshops at all and 70 percent of existing workshops lack of many requirements of Ideal workshops in terms of typical dimensions, internal divisions, contents and not taking into account the comfortable area of work within the workshop without overlapping of workers during the performance of their duties.

Despite of this inability; it is found that the effectiveness of available workshops relatively high. So 36.7 percent of them, their efficiency between 60-90 percent.

With regard to the workers in these workshops (biomedical engineers and technicians); it is found that the number of them not exceed two persons regardless of operating capacity and this representing 23 percent of hospitals under the study.

The results showed that; the obstacles are not confined to the building of workshop but in the awareness of the working group (biomedical engineers and technicians) (HAT), where the largest proportion is 40 percent of results reflex 20 percent of awareness of (HAT).

The results showed that; the high awareness of working group (biomedical engineers and technicians) of their effective role in the efficiency of the hospital's performance, where 36 percent of results reflex 60%-90 % percent of awareness.

Chapter Seven

Conclusion and Recommendations

7.1 Conclusion:

Hospitals are the facility to deliver health service to patient, to ensure that this service is proper; we should assess the working equipment well. This assessment should be done by biomedical engineering workshop.

In this project, 30 biomedical engineering workshops was assessed based on hospital capacity and its ideal workshop.

A comparison between the ideal workshop stated by WHO and the workshops under study was done to represent the weakness points on it.

It was found that in all hospitals under the study the workshops are not typical workshops for biomedical engineering department depending on operating capacity of these hospitals in beds.

7.2 Recommendations:

- Establish a binding law for hospitals to provide a suitable environment for biomedical engineers in order to enable them to perform their job in a proper way, to be monitored by the Ministry of Health**.**
- There should be specialists in the Ministry of Health to conduct training courses in the field of Health Technology Assessment.
- Every biomedical engineer should have an idea of what dose job description mean.
- The Ministry of Health must play an important role in obliging the hospitals to appoint a sufficient number of biomedical engineers depending on hospitals' capacity, which enables them to monitor the medical devices at the hospitals in the best way. So, this leads to guaranty the efficiency of this equipment.

- Continuous training of biomedical engineer ensures the efficiency of performance.
- Separated management department for biomedical engineers at ministry of health

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Appendixes

Appendixes

Appendix [A]: The Questionnaire

Sudan University of Science and Technology

College of Graduate Studies

College of Engineering

Biomedical Engineering Department

Visual Inspection of Current Situation of Biomedical Workshops at Hospitals

This research aims to evaluate the current situation in the biomedical engineering work shops, so we can establish an ideal biomedical work shop at hospital in Khartoum state and achieve high availability for the medical equipment.

1. What is your job title?

   Manager ☐ Physician ☐ Clinical engineer ☐

2. How many years of your professional experience?

   Less than 5 years ☐ 5-10 years ☐ More than 10 years ☐

3. What is the type of your hospital?

   I. Public sector. ☐

   II. Private sector. ☐

   III. Have both types. ☐

4. How much the full operating capacity of the hospital (in beds):

Less than 50 ☐ 50<100 ☐ 100<200 ☐ more than 200 ☐

5. Is there an Ideal Biomedical work shop at hospital?

   Yes ☐ No ☐

6. How many employee(s) do you have in biomedical work shop?

   One ☐ two ☐ three ☐ four ☐ five ☐ more than five ☐

7. What are the types of specialties at your work shop?(you can choose more than one choice)

   I. Clinical engineer(s) ☐

   II. Electrical engineer(s) ☐

   III. Technician(s) ☐

8. In percentage to how much this work shop enough or suitable for the hospital and matching the needs of hospital in terms of caring of medical equipment?

   20% ☐ 30%-%50 ☐ 60%-%90 ☐ more than %90 ☐

9. In percentage to how much do you have an idea about Health Technology Assessment (HTA)?

   20% ☐ 30%-%50 ☐ 60%-%90 ☐ more than %90 ☐

10. In percentage to how much do you aware of biomedical engineers working at HTA agencies or at hospitals contributing to a health team?

    20% ☐ 30%-%50 ☐ 60%-%90 ☐ more than %90 ☐

11. In which areas of the assessment process are the biomedical engineers involved? [27] (You can choose more than one if you have)

    I. Inspection, preventive and Corrective maintenance for medical equipment at the hospital. Yes ☐ No ☐

    II. Prepare and update technical specifications for medical equipment. Yes ☐ No ☐

    III. Providing studies for future extension at hospital on the needs of medical equipment. Yes ☐ No ☐

    IV. Training undergraduates' students and new graduates from public and Privet University. Yes. ☐ No. ☐

V. Train the medical staff and technical staff on the proper use of medical equipment. Yes ☐ No ☐

VI. Carry out purchase orders of spare parts and medical equipment supplies. Yes ☐ No ☐

VII. Prepare and follow up approvals and purchase decisions. Yes ☐ No ☐

VIII. Manage the financial guarantees related to purchase processes. Yes ☐ No ☐

IX. Manage the central stores (reception, storage and dispense spare parts and medical equipment accessories). Yes ☐ No ☐

X. Keep information records on vendors and evaluate their performance. Yes ☐ No ☐

12. Do you have job description of biomedical engineers at your hospital?

Yes ☐ No ☐

(If yes, would you include the description please?)

13. In percentage to how much does your current work shop match the ideal one?

20% ☐ 30%-%50 ☐ 60%-%90 ☐ more than %90 ☐

14. In terms of service contract, what the types of contracts do you have? [27]

I. In house contract. Yes ☐ No ☐

II. Local agents' contract. Yes ☐ No ☐

15. If you have local agents' contract, is the biomedical work shop do the following : [27]

I. Supervise all matters related to agreements and maintenance contracts entered into with local agents. Yes ☐ No ☐

II. Supervise the maintenance of the medical equipment during the free warranty period. Yes ☐ No ☐

III. Supervise and follow up reception of the medical equipment. Yes ☐ No ☐

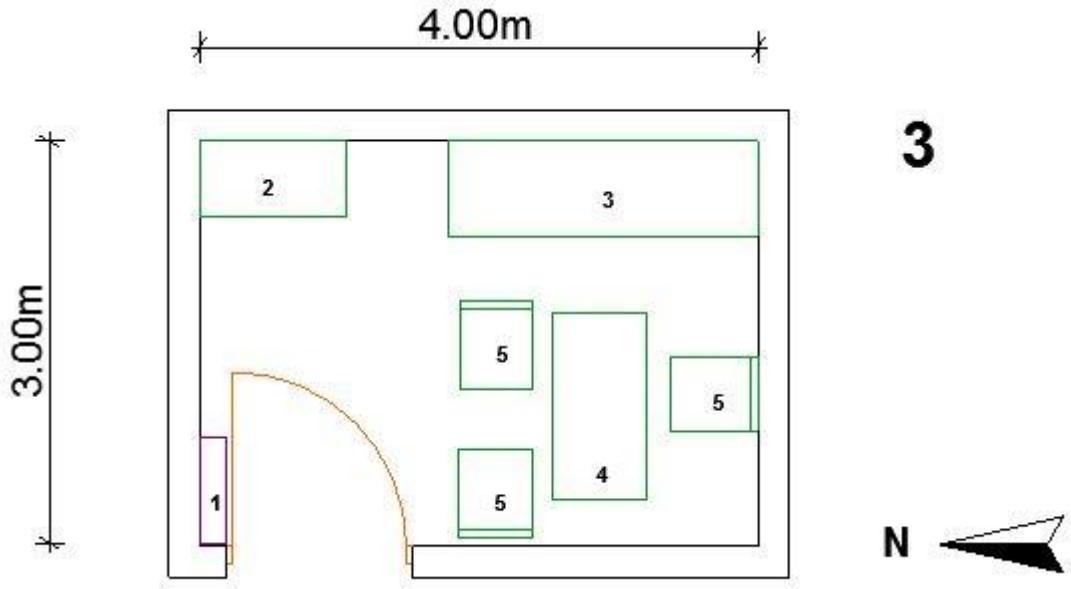
16. What is the type of documentation at biomedical work shop?

I. Paper. Yes ☐ No ☐

II. Computerized. Yes ☐ No ☐

Appendix [B]: Samples those have capacity in beds [100<200 and more than 200]

Sample Three:



1: An air conditioning.

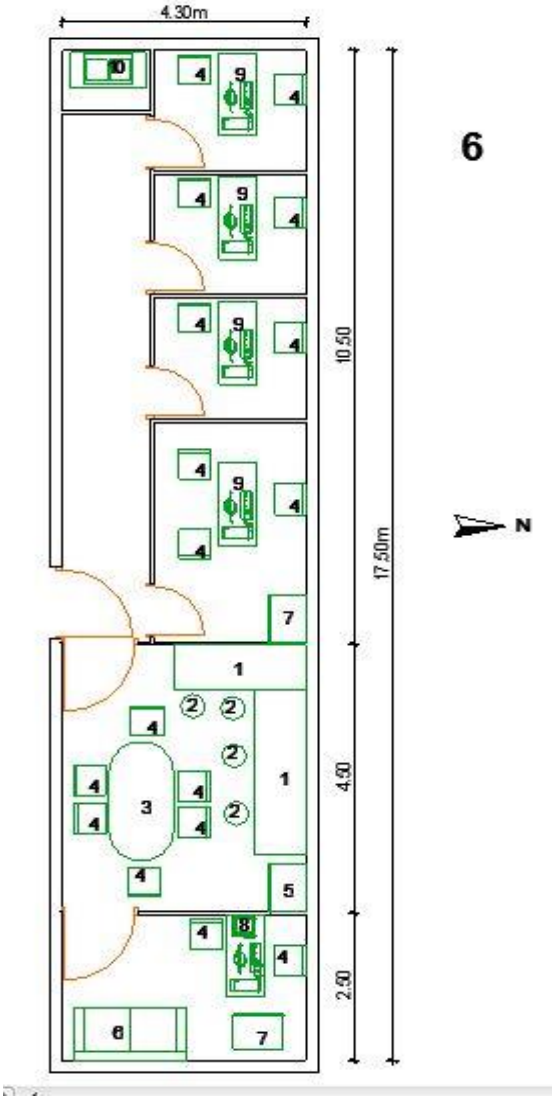
2: A cupboard contains electronics' repair tools, spare parts, manuals and documents' file.

3: A bench for repairing equipment.

4: An office desk with computer.

5: Chairs.

Sample Six:



1: Benches for repairing equipment.

2: Stools.

3: A meeting table.

4: Chairs.

5: A cupboard contains electronics' repair tools, spare parts and manuals.

6: A sofa.

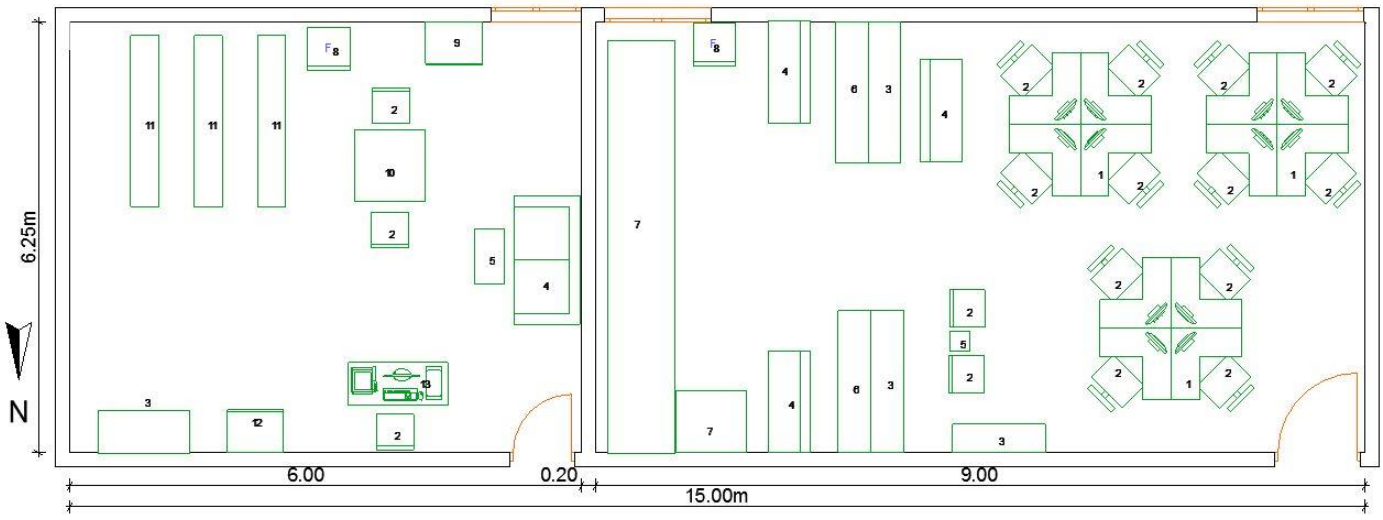
7: An office cabinet.

8: An office desk with computer and printer.

9: An office desk with computer.

10: A washbasin.

Sample Seven:



1: Office desks with computers.

2: Chairs.

3: Cupboards contain electronics' repair tools, spare parts and documents' file.

4: Sofas.

5: Coffee tables.

6: Shelves for unrepaired medical equipment.

7: Benches for repairing equipment.

8: Refrigerators.

9: An office cabinet.

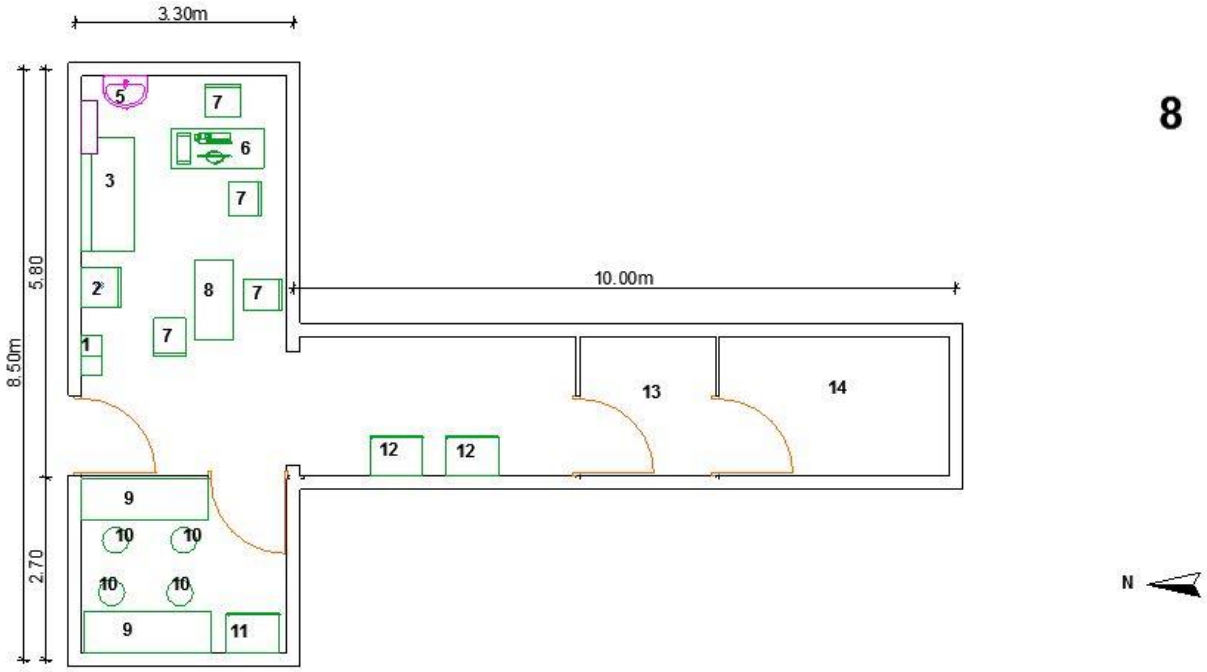
10: Reading table.

11: Shelves contain manuals.

12: A drawer for equipment accessories.

13: An office desk with computer and printer.

Sample Eight:



1: A closet.

2: A refrigerator.

3: A sofa.

4: An air conditioning.

5: A basin.

6: An office desk with computer.

7: Chairs.

8: An office desk.

9: Benches for repairing equipment.

10: Stools.

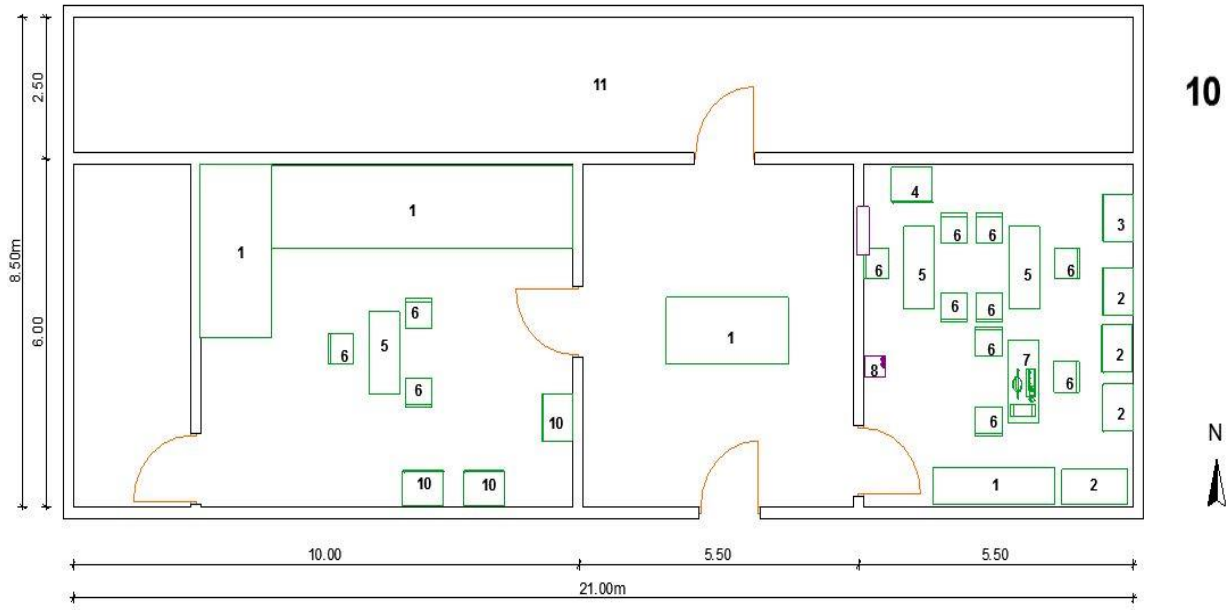
11: Drawers for electronics' repair tools and manuals.

12: Cupboards contain documents' file.

13: A store for consumables and spare parts.

14: A store for scrap of medical equipment.

Sample Ten:



1: Benches for repairing equipment.

2: Cupboards contain spare parts.

3: A cupboard contains electronics' repair tools and manuals.

4: A cupboard contains documents' file.

5: An office desk.

6: Chairs.

7: An office desk with computer.

8: A water cooler.

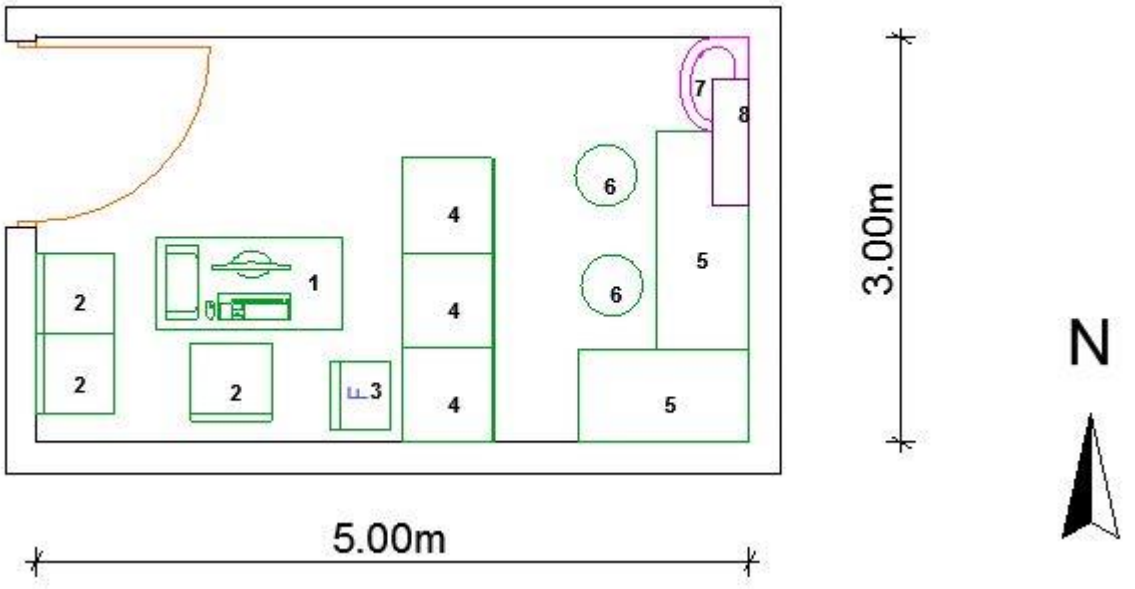
9: An air conditioning.

10: Cupboards contain electronics' repair tools.

11: A store for scrap of medical equipment.

Sample Eleven:

11



1: An office desk with computer.

2: Chairs.

3: A refrigerator.

4: Cupboards contain electronics' repair tools, spare parts, manuals and documents' file.

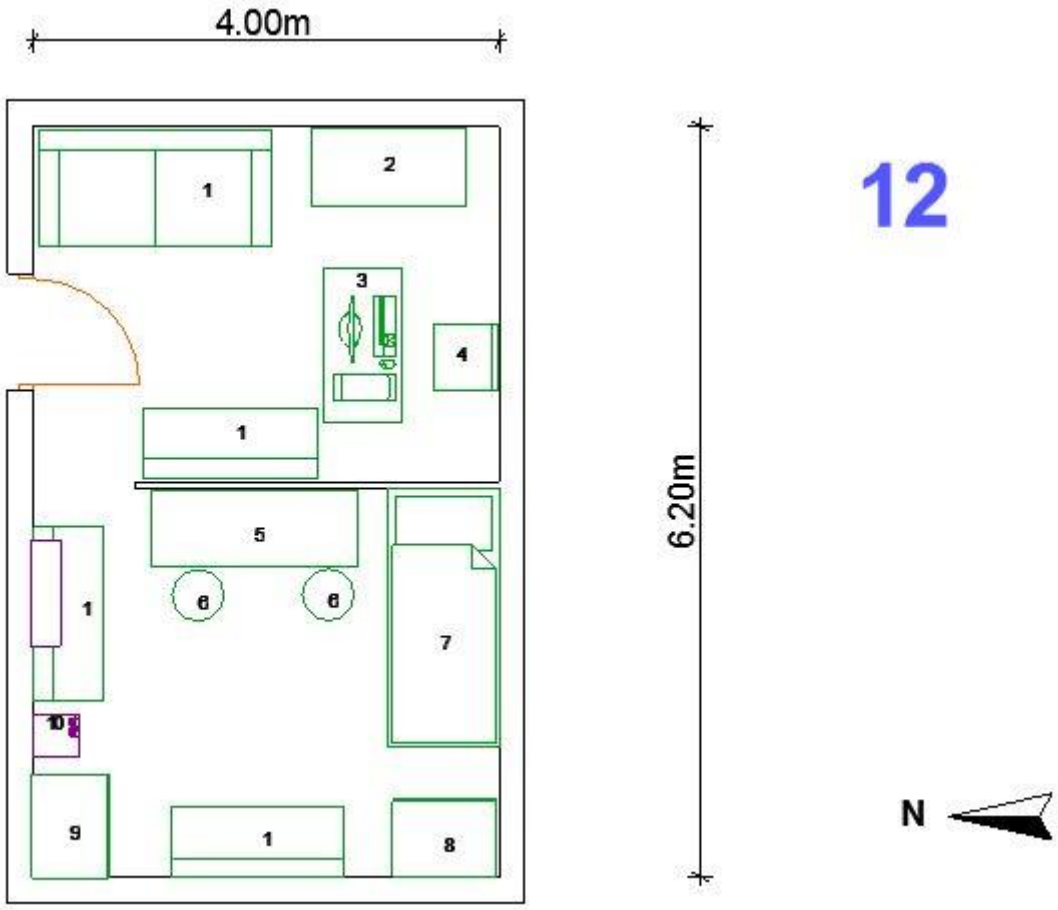
5: Benches for repairing equipment.

6: Stools.

7: A basin.

8: An air conditioning.

Sample Twelve:



1: Sofas.

2: An office desk for keeping electronics' repair tools and spare parts.

3: An office desk with computer.

4: A chair.

5: A bench for repairing equipment.

6: Stools.

7: A rest bed for on call biomedical engineer.

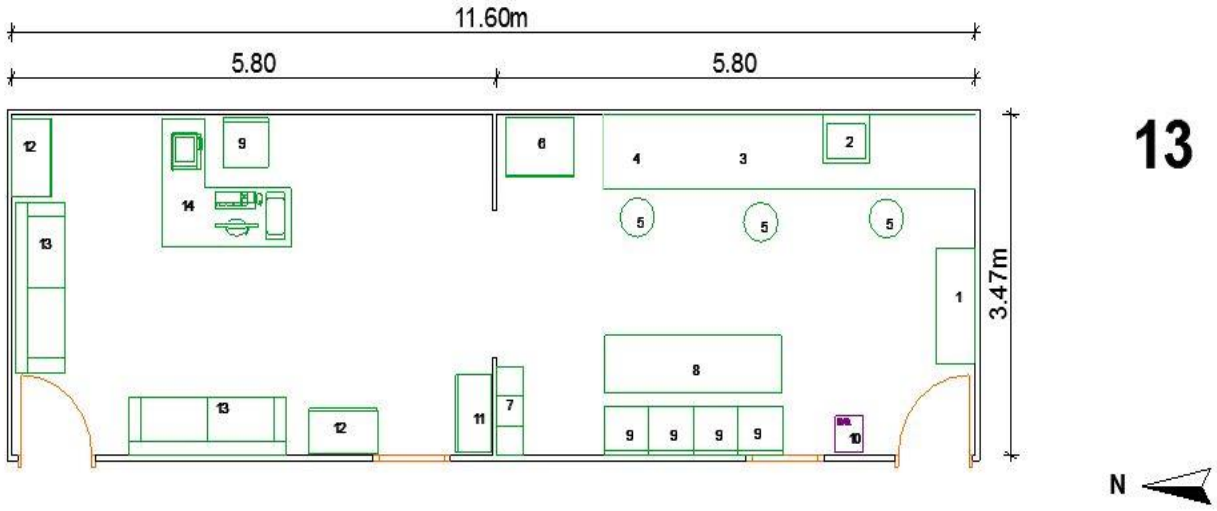
8: A cupboard contains out of use medical equipment.

9: A cupboard contains documents' file.

10: A water cooler.

11: An air conditioning.

Sample Thirteen:



1: Shelves for out of use equipment.

2: A washbasin.

3: An electronic bench for repairing equipment and keeping electronics' repair tools.

4: A mechanical bench.

5: Stools.

6: A cupboard contains spare parts.

7: Lockers.

8: An office desk.

9: Chairs.

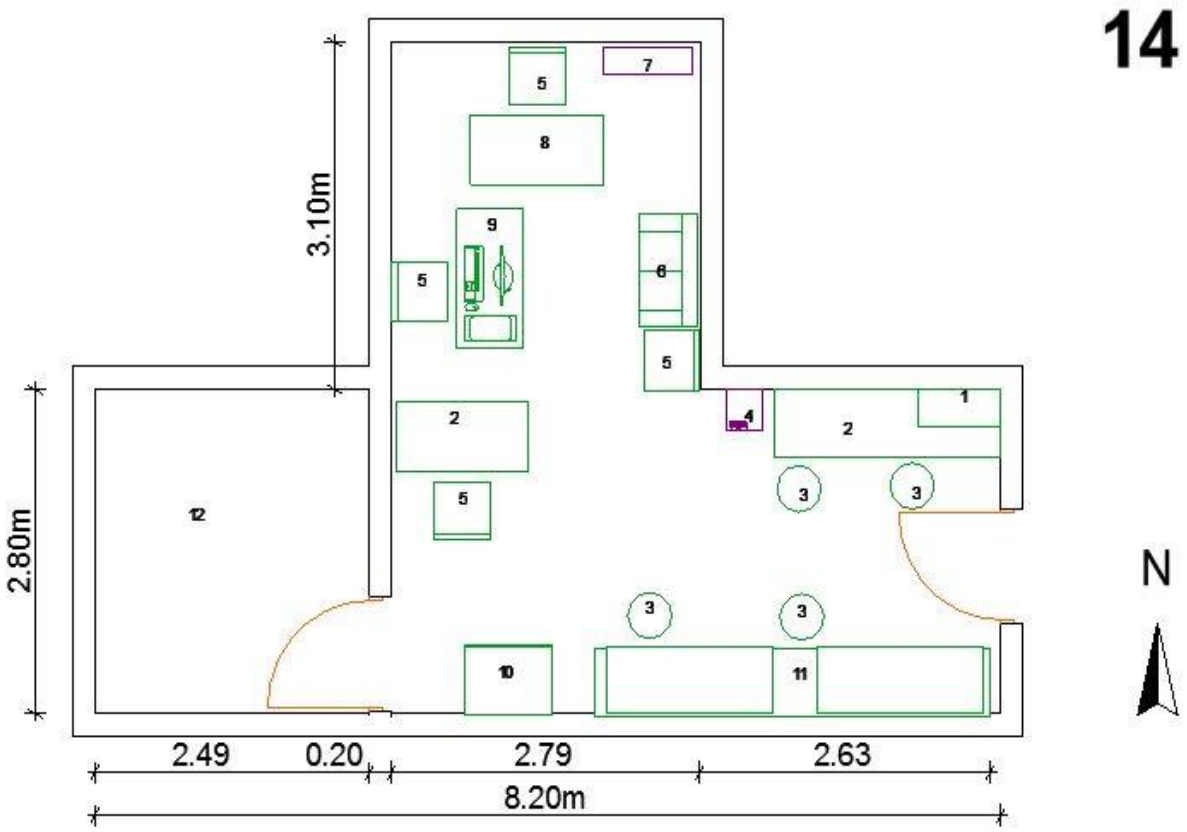
10: A water cooler.

11: A cupboard contains manuals.

12: A cupboard contains documents' file.

13: Sofas.

Sample Fourteen:



1: Drawers for Fuses' spare parts.

2: Benches for repairing equipment.

3: Stools.

4: A water cooler.

5: Chairs.

6: A sofa.

7: An air conditioning.

8: An office desk.

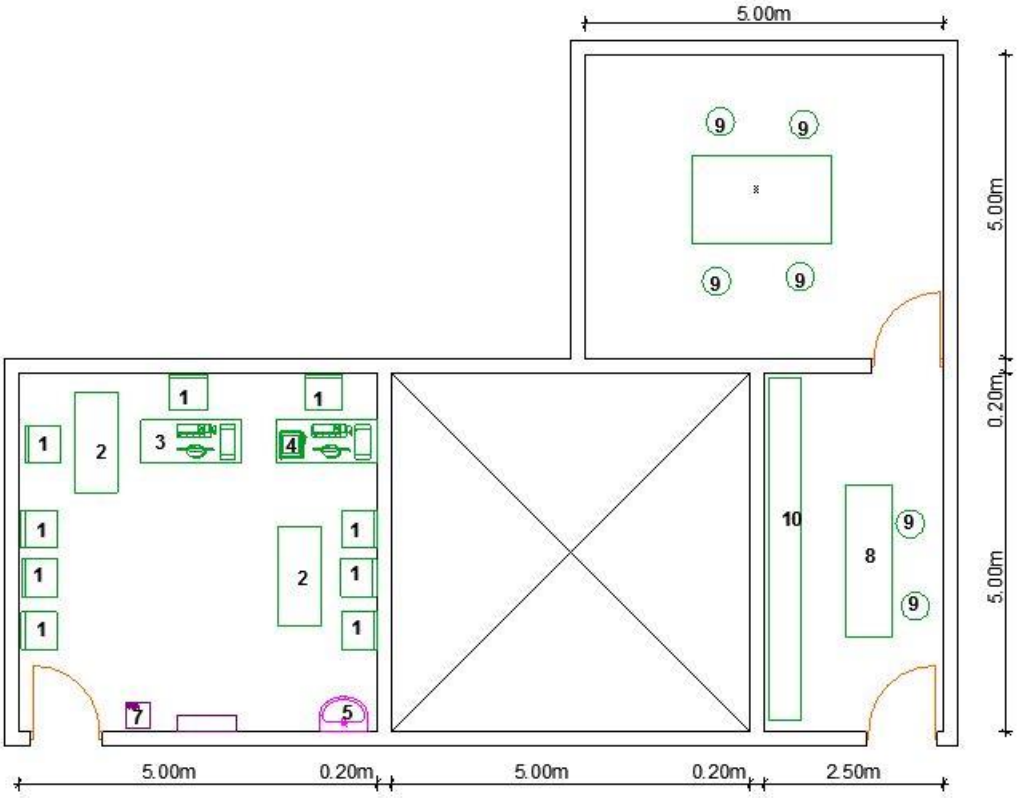
9: An office desk with computer.

10: A cupboard contains spare parts and documents' file.

11: A bench with drawers for repairing equipment and keeping electronics' repair tools.

12: A store for scrap of medical equipment.

Sample Fifteen:



1: Chairs.

2: An office desk.

3: An office desk with computer.

4: An office desk with computer and printer.

5: A basin.

6: An air conditioning.

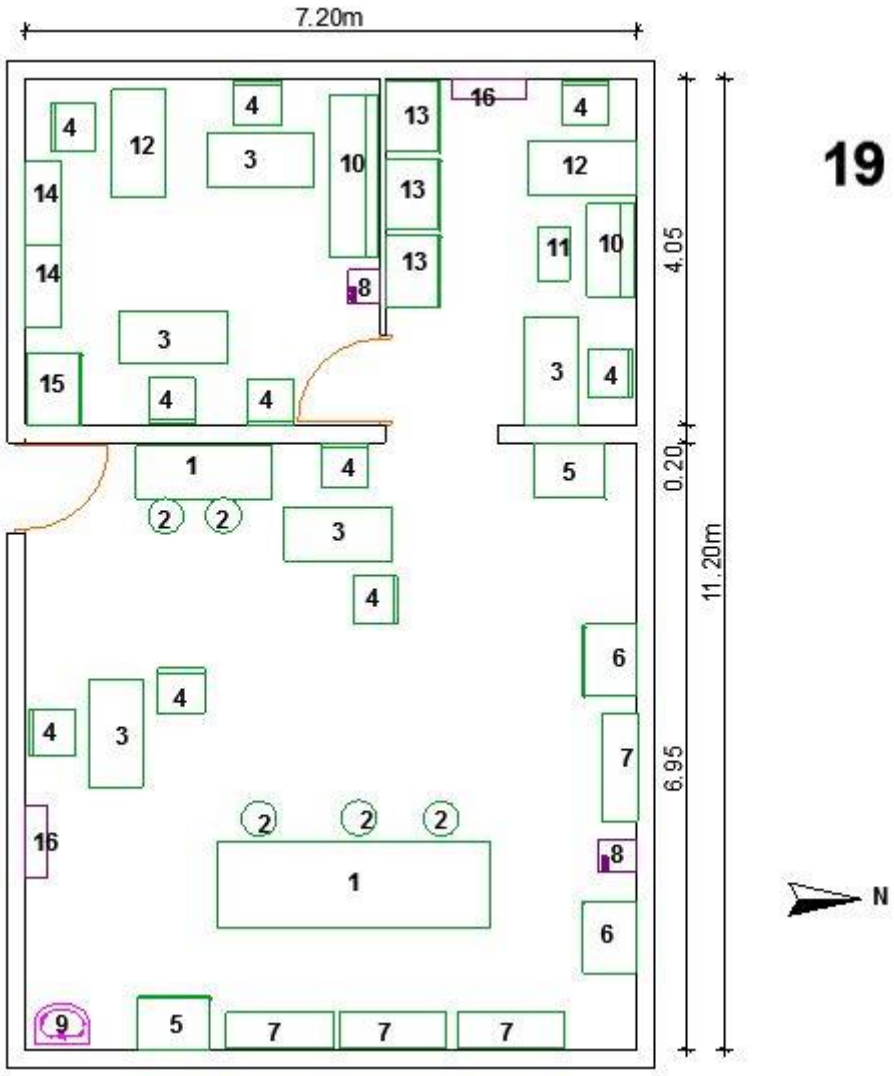
7: A water cooler.

8: Benches for repairing equipment.

9: Stools.

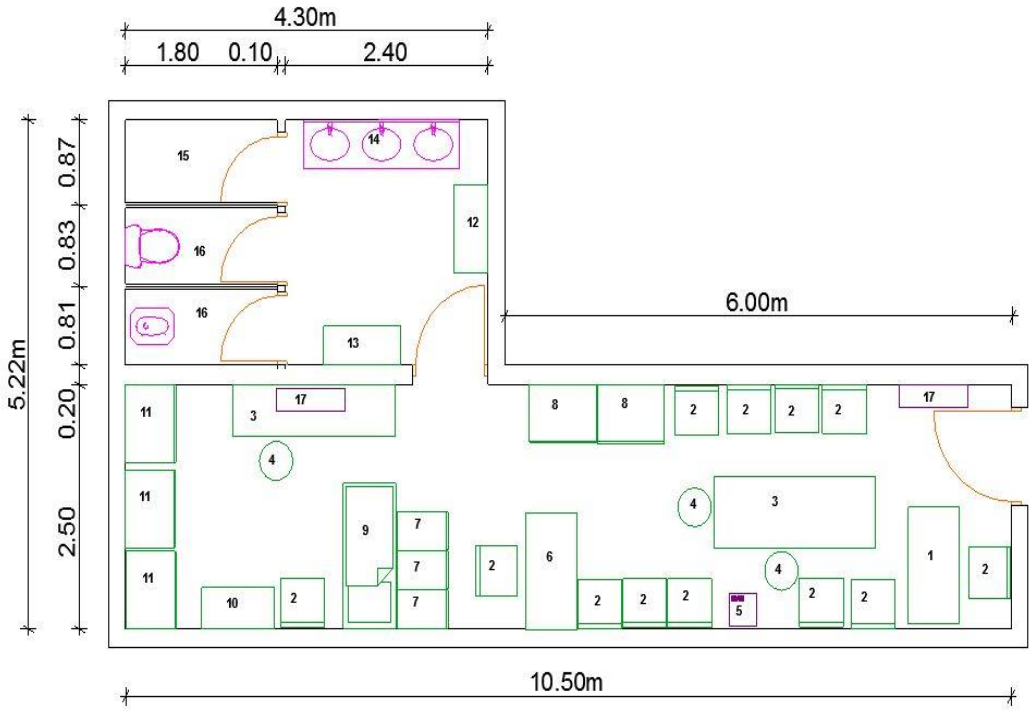
10: Shelves for out of use equipment.

Sample Nineteen:



1: Benches for repairing equipment.
2: Stools.
3: Office desks.
4: Chairs.
5: Drawers contain manuals.
6: Cupboards contain electronics' repair tools.
7: Shelves for out of use and under repair equipment.
8: Water coolers.
9: A basin.
10: Sofas.
11: A coffee table.
12: Office desks with computers.
13: Cupboards contain accessories of equipment
14: Shelves contain documents' file.
15: Drawers contain spare parts.
16: Air conditioning.

Sample Twenty- one:



21

1: An office desk.

2: Chairs.

3: Benches for repairing equipment.

4: Stools.

5: A water cooler.

6: An office desk with computer.

7: Drawers contain spare parts.

8: Cupboards contain electronics' repair tools.

9: A rest bed for on call biomedical engineer.

10: Shelves contain electronics' repair tools.

11: Cupboards contain documents' file.

12: Shelves for out of use equipment.

13: Shelves for in use equipment.

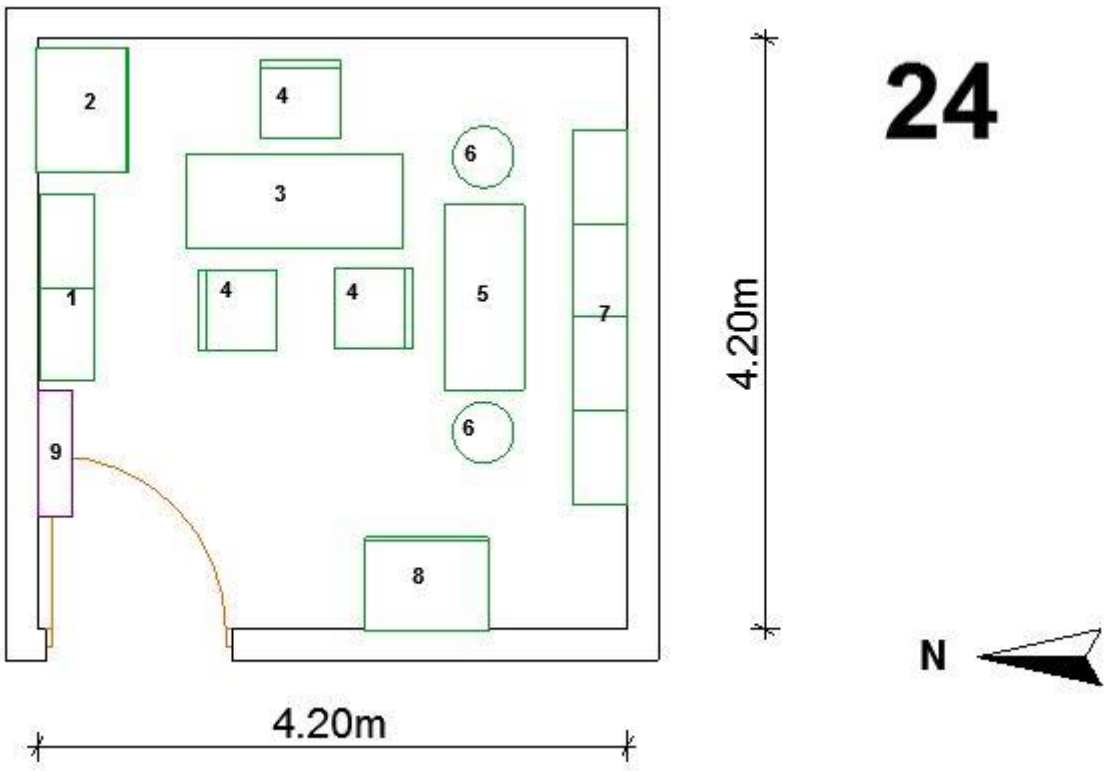
14: A washbasin.

15: A shower.

16: Bathrooms.

17: An air conditioning.

Sample Twenty- four:



1: Shelves contain electronics' repair tools.

2: A cupboard contains spare parts, manuals and documents' file.

3: An office desk.

4: Chairs.

5: A bench for repairing equipment.

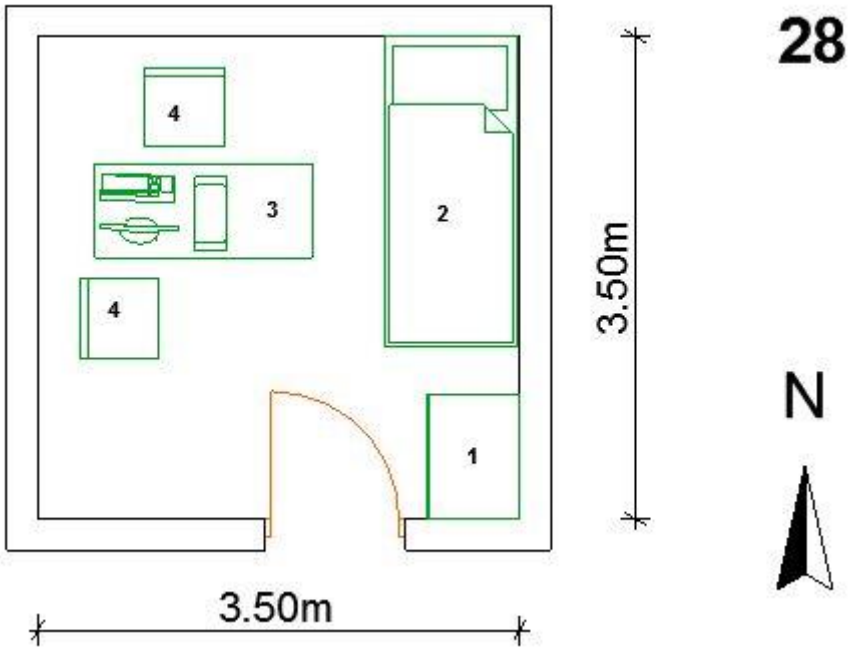
6: Stools.

7: Shelves for out of use and scrap of equipment.

8: A cupboard contains repaired and under repair equipment.

9: An air conditioning.

Sample Twenty-eight:



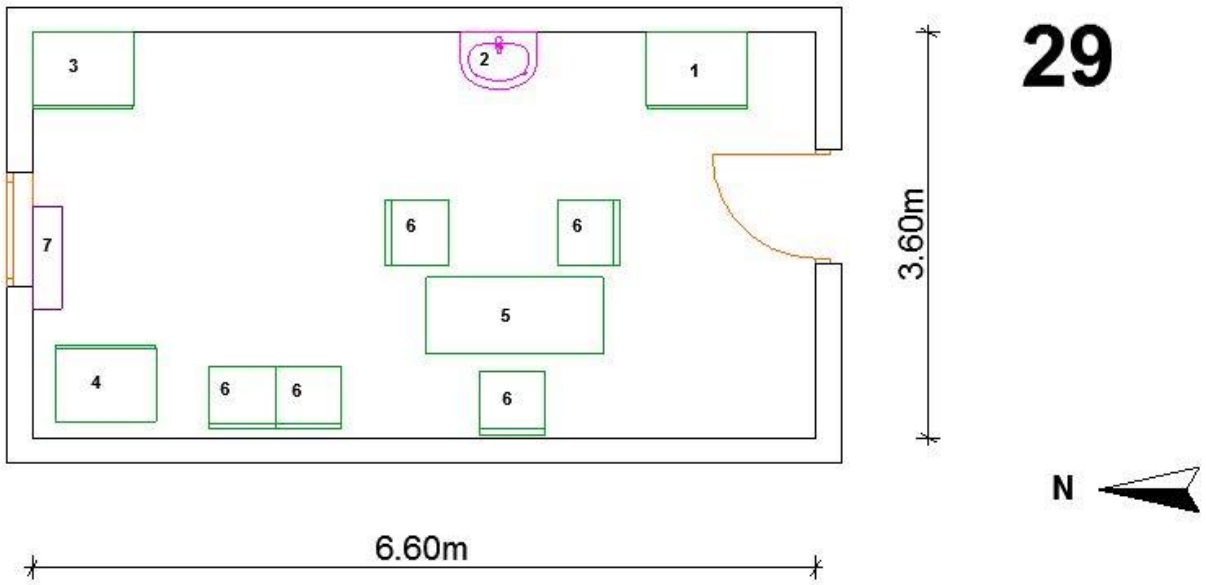
1: A cupboard contains electronics' repair tools, new equipment, manuals and documents' file.

2: A rest bed for on call biomedical engineer.

3: An office desk with computer.

4: Chairs.

Sample Twenty-nine:



1: Drawers for spare parts.

2: A basin.

3: A cupboard contains manuals and documents' file.

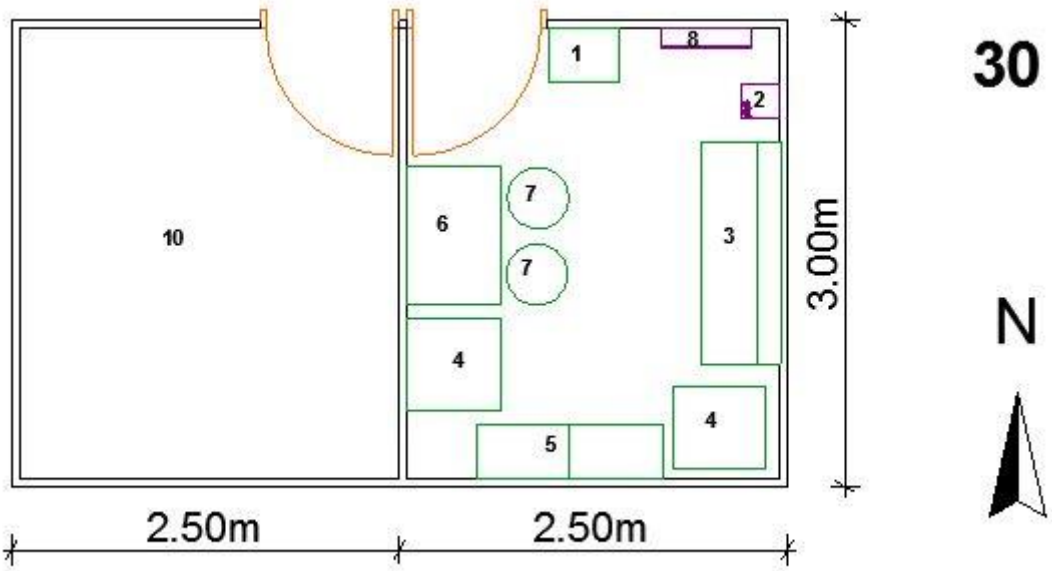
4: A cupboard contains electronics' repair tools.

5: An office desk.

6: Chairs.

7: An air conditioning.

Sample Thirty:



1: A coffee table.

2: A water cooler.

3: A sofa.

4: Office desks for under repair equipment.

5: Shelves contain spare parts.

6: A bench for repairing equipment.

7: Stools.

8: An air conditioning.

9: A store for scrap of medical equipment.