

**SCHOOL OF PUBLIC HEALTH
COLLEGE OF HEALTH SCIENCES
UNIVERSITY OF GHANA**



**ASSESSMENT OF BIOMEDICAL EQUIPMENT UTILIZATION IN NKENKAASU
GOVERNMENT HOSPITAL, ASHANTI REGION**

BY

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**THIS DISSERTATION IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON,
IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE
MASTER OF HEALTH ECONOMICS DEGREE**



DECLARATION

This is to declare that this dissertation is the result of my own research. Published literatures of other research which have been cited have been duly acknowledged by means of referencing.

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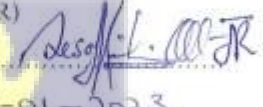
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DEDICATION

I dedicate this work to my family and World Health Organization, Ghana. I trust my work would help enhance the management of medical equipment in Ghana.



ACKNOWLEDGEMENT

My principal gratitude goes to the almighty God for His immeasurable grace and mercies that has brought me this far. My profound gratitude also goes to my supervisor, Prof. Moses Aikins for his fatherly love, motivation and comments that made the completion of this work possible.

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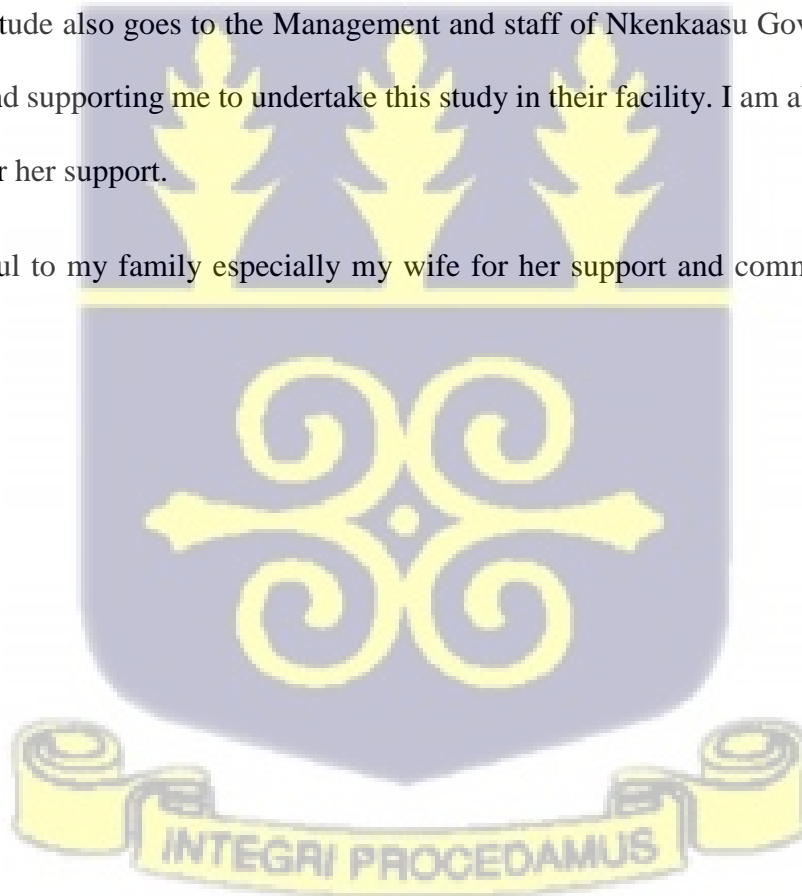


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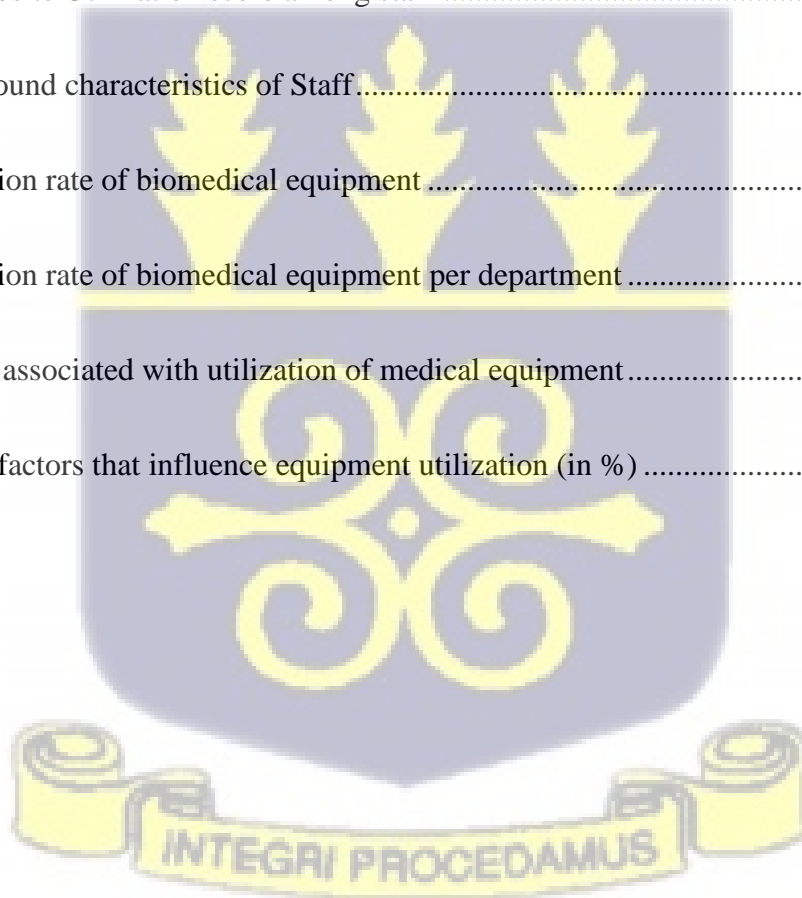
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LIST OF ABBREVIATIONS

CAT	Caterpillar
CNPH	Camarines Norte Provincial Hospital
CoA	Commission on Audit
CSCMP	Council of Supply Chain Management Professionals
CT	Computerized Tomography
BE	Biomedical Equipment
ECG	Electrocardiogram
EIRS	Engine Idle Reduction System
ENT	Ear, Nose and Throat
FAO	Food and Agriculture Organization
FBC	Full Blood Test
G6PD	Glucose-6-Phosphate Dehydrogenase
GHS-ERC	Ghana Health Service Ethics Review Committee
Hb	Haemoglobin
IGNOU	Indira Gandhi National Open University
LMICs	Low- and Middle-Income Countries
ME	Medical Equipment
MEHT	Medical Equipment and Healthcare Technology
MHRA	Medicines and Healthcare products Regulatory Agency
PMH	Productive Machine Hours
ROC	Return on Cost

ROI	Return on Investment
RP	Replacement Programme
SMH	Scheduled Machine Hours
UC	Utilization Co-efficient
WHO	World Health Organization



DEFINITION OF OPERATIONAL TERMS

Breakdown rate: It is the ratio of the time equipment is down against planned operating time multiplied by 100%

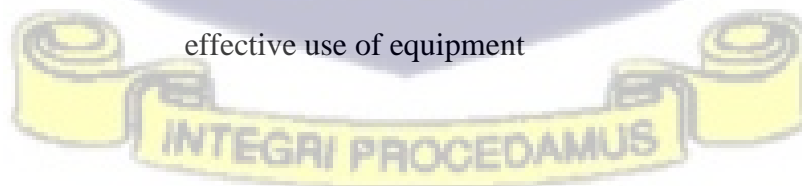
Equipment downtime: Equipment downtime is the period of time that equipment is not in use, whether as a result of unforeseen equipment failure or scheduled downtime needed to undertake preventive maintenance.

Equipment utilization: Equipment utilization is the percentage of the scheduled time that the equipment is expected or is really working.

Medical equipment: It is a tool, gadget, software, appliance, or other product used either alone or in conjunction with other tools for management of health condition

Return on Investment: The ratio of net income (over time) to investment

Utilization rate: It is a metric for measuring the efficient and effective use of equipment



ABSTRACT

Background: The availability and effective use of medical equipment in healthcare facilities have an impact on the delivery of high-quality diagnosis services and clinical patient management. In this era of high-cost medical treatment, every piece of equipment put in health-care institutions must be used to its utmost potential. Utilization index is a way of determining the functionality of equipment. An efficient use of the equipment might lead to best patient care and quick turnaround, as well as the lowest possible cost, highest possible quality of treatment, and patient satisfaction. The utilization rate is affected by characteristics of the equipment, internal and external factors.

Objective: The general objective of the study is to assess biomedical equipment utilization in Nkenkaasu Government Hospital, Ashanti Region.

Methods: The study was a cross-sectional study design with quantitative data collection method. In all, 45 medical equipment in selected 6 functional units were assessed for their utilization factors and indicators. Medical personnel who used the medical equipment were interviewed using a structured questionnaire to assess their perception on factors affecting utilization.

Outcome: The study revealed that on average 53.8% of the equipment were underutilized. Utilization got affected due to a number of days wasted due to break down or any other reason. The most affected was nebulizer which recorded the highest breakdown rate of 9% had a utilization rate of 38%. The microscope showed the quickest return on investment of 11 months. Working hours had a significant relationship with utilization.

Conclusion: Estimation of utilization of medical equipment in a health facility is crucial for procurement planning. Utilization of biomedical equipment is affected by factors such as working hours.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Increasing operational efficiency and lowering costs while enhancing patient service are perennial challenges in the current health-care environment. Medical treatment has been transformed by technological and engineering advancements, especially in recent decades (Lathwal & Banerjee, 2001). Within the system for delivering healthcare, medical equipment is extremely important. The Alma-Ata Declaration of 1978 has placed a strong emphasis on the availability and use of varied equipment for healthcare at all levels of the healthcare system in order to provide effective and efficient service delivery (Chaudhary & Kaul, 2014).

Medical equipment is defined as an instrument, appliance, substance, or other product that may be used alone or in conjunction with software to diagnose, prevent, treat, monitor or relieve a health condition (MHRA, 2011). Medical equipment is used for a variety of reasons in health care delivery, including illness diagnosis and treatment, as well as rehabilitation following diseases or accidents. This medical device can be used independently or in combination with a number of accessories, consumables, or other medical tools. (WHO, 2011)

The issue of effective medical equipment usage has been brought to the forefront of the present healthcare system (Mengqi, 2015). Furthermore, because of its significant implications for healthcare expenditures, the relationship between hospital features and the use of high-tech medical equipment has gained increased attention (Yan, Hao, & Jingsong, 2018).

Lack of maintenance, misuse, acquiring unnecessary devices, and poor training on the operation of medical equipment were all factors that affected the usage of medical equipment

(Ademe, Tebeje, & Molla, 2016). Medical equipment that was rarely maintained, was prone to breakdown (Bahreini, Doshmangir, & Imani, 2019). A lack of strategic planning in medical equipment management, particularly purchasing of equipment at the right time, right place, and with the proper maintenance agreement, affects usage rate (Suji & Vaanmathi, 2020). An efficient use of the equipment might lead to best patient care and quick turnaround, as well as the lowest possible cost, highest possible quality of treatment, and patient satisfaction. (Hospital Equipment utilization, 2008)

In many circumstances, the hospital's maintenance program is not optimized; instead, hospital managers just rely on the operating expertise of the manufacturer or technician (Bloom, 2006). As a result, the hospital may fail to pick the most appropriate maintenance program for their business, resulting in wasteful expenditures for equipment maintenance. The issue becomes more serious when equipment fails often despite the implementation of all maintenance programs. Rather than finding the source of the problems, these breakdowns were occasionally rectified. Effective utilization of medical equipment requires priority, expanding the number of investigations and provision of cost-effective and high-quality therapy (Sontea, Morgoci, Turcanu, & Pislaru, 2016). Medical equipment efficiency is one of the issues that management in the healthcare delivery system usually overlooks, which can result in losses by lowering output. Poor preventive maintenance of equipment will lead to lower diagnostic and treatment standards, as well as higher maintenance costs (Gupta, Gupta, Sarode, Sarode, & Patil, 2017). The utilization index is one of the critical indicators for monitoring the functionality of medical devices or it is the metric for determining the performance of devices (Hospital Equipment Utilization, 2008). Understanding equipment utilization is a pre-requisite for attaining realistic performance of medical equipment.

Ineffective use of medical technology has limited the ability of healthcare providers to offer quality medical treatment. The optimal use of these medical equipment leads to maximization of return on investment. Studies on the use of equipment is necessary to ensure efficient utilization. The optimal use of these medical equipment leads to maximization of return on investment.

1.2 Problem Statement

In Sub-Saharan Africa, hospitals and research facilities now have access to a variety of medical technologies that have the potential to enhance healthcare (Bryce & Clin, 1998). The use of these technologies in service delivery provides increased productivity and quality, which results in patient care that is both efficient and affordable (Donabedian, 2005). In many LMICs the availability of medical equipment does not always imply enhancements to the delivery of medical services in hospitals (Howie, Hill, Peel, Sanneh, Njie, Hill, Mulholland & Aclegbola, 2008). Indeed, managing the supply of top-notch medical treatment under resource-limited environments continues to be a challenge for health institutions around the world (Odedra, Lawrie, Bennett & Goodman, 1993) To meet their needs for healthcare and research technologies, most Sub-Saharan countries heavily rely on donations of medical equipment (Dohn & Dohn, 2003). Many LMICs receive up to 80% of the medical equipment as gifts or funding from foreign governments or international donors (WHO, 2011). About 40 - 70% of medical devices in LMIC are malfunctioning and ineffective (Perry & Malkin, 2011).

According to Emmerling, Dahinten & Malkin, (2018) majority of these devices are either not used enough, are not well maintained, or are out of operation, due to a variety of reasons, including the challenge of locating replacement parts, components and consumables. The elevated rate of malfunctioning equipment is also ascribed to factors such as escalating medical

device expenses, unreliable water and power supply, a shortage of public facilities like air-conditioned areas and ineffective planning (Bryce & Clin, 1998 and Malkin, 2007). The issue is made worse by the fact that many countries are unable to fully capitalize on the available technologies. Even before equipment is used there is an average depreciation of 30% as a result of inaccurate specifications and over-sophistication, excluding normal depreciation (WHO, 2006). Once the equipment is in use, its value decreases even more due to factors including illogical use, a lack of inspections, scheduled maintenance, and contractual repair agreements with suppliers, as well as a shortage of replacement components. This causes a further one tenth drop in the original investment value of the equipment.

Globally, access and effective use of technologies improve the quality of health of people (Donabedian, 2005). Thus, having functional equipment is crucial. In Sub-Saharan Africa, where there are 24% of the world's diseases, 1% of the world's financial resources, and 3% of the world's human resource potential, this is an especially critical issue (Anyangwe & Mtonga, 2007). The quality of healthcare delivery and research in LMICs is severely hampered by a lack of functional equipment, which also has an impact on the healthcare system as a whole (Ademe, Tebeje & Molla, 2016)

Designing unique medical equipment fit for sub-Saharan Africa settings, implementing regulations on donations and equipment acquisition, educating Biomedical Engineers locally to improve technical support – all of these have been done to address the issues in medical equipment management (Ploss, Douglas, Glucksberg, Kaufmann, Malkin, McGrath, Mkandawire, Oden, Osuntoki, Rollins, Sienko, Ssekitoleko, & Reichert, 2017). There is limited public data on how these programs have initiatives have enhanced the utilization of medical equipment, especially in

LMICs. The study is focused on assessing the use of medical equipment in several functional healthcare delivery areas of Nkenkaasu Government, Ashanti Region.

Nkenkaasu Government Hospital is a district hospital in the Offinso North District. Like any district hospital in Ghana, it provides primary healthcare to the population in the catchment area and people from adjoining districts. It also serves as a referral point for the health centers and other clinics in the district. The facility reported increasing cases of equipment break down in the 2021 Annual Performance Review of the hospital. The situation led to high maintenance cost and ultimately affected quality of healthcare. More so, Nkenkaasu Government Hospital is a model hospital whose characteristics are like most of the district hospitals in Ghana. Therefore, information from this study can be used by managers and policy makers on effective and efficient use of medical equipment.

1.3 Justification

The study provides vital information to healthcare managers and policymakers on optimal use of medical equipment. The data gathered in the study would identify gaps in the medical equipment utilization factors and these affect the use of these equipment in public health facilities. Such information would lead to improvement in decision making, especially procurement of medical equipment. Studies on the utilization of medical equipment, especially in the Lower Middle-Income Countries are limited. The study would provide one of the foundation stones for further studies on utilization of medical equipment in the delivery of healthcare in Ghana.

1.4 General Objective

The general objective of the study is to assess biomedical equipment utilization in Nkenkaasu Government Hospital, Ashanti Region

1.4.1 Specific Objectives

The specific objectives are:

1. To estimate the utilization rate of biomedical equipment
2. The estimate the breakdown rate of biomedical equipment
3. To estimate the return on investment of biomedical equipment
4. To determine the utilization factors associated with biomedical equipment.

1.4.2 Research Questions

1. What is the utilization rate of biomedical equipment?
2. What is the breakdown rate of the biomedical equipment?
3. What is the return on investment in these biomedical equipment?
4. What factors affect utilization of these equipment (Staff Training, Maintenance Policy, Working Hours, Procurement Policy, electricity power stability, temperature, and consumables/ spare parts)

1.5 Conceptual Framework for Utilization of Medical Equipment

Staff training, policy for managing medical equipment, procurement policy, and environmental factors have all been recognized as factors that influence medical equipment utilization (Guyow, Tenambergen & Oluoch, 2021). The manufacturer's name and the equipment's modality and age have also been identified as features that can affect the dependability of medical equipment. (Badnjević, Gurbeta Pokvić, Hasičić, Bandić, Mašetić, & Kovačević, 2019 and Kovacevic, Pokvic, Spahic & Badnjevic, 2019).

According to Siti Hajar, Saiful Amri & Siti Aisyah, (2019), medical equipment breakdown can be caused by a number of variables, including the type of maintenance services, the environment, users, and equipment condition. These characteristics of the medical equipment, the institutional and environmental factors are the independent variables and utilization indicators are the dependent variable as seen in Figure 1. The conceptual framework was constructed from review of various related literatures.

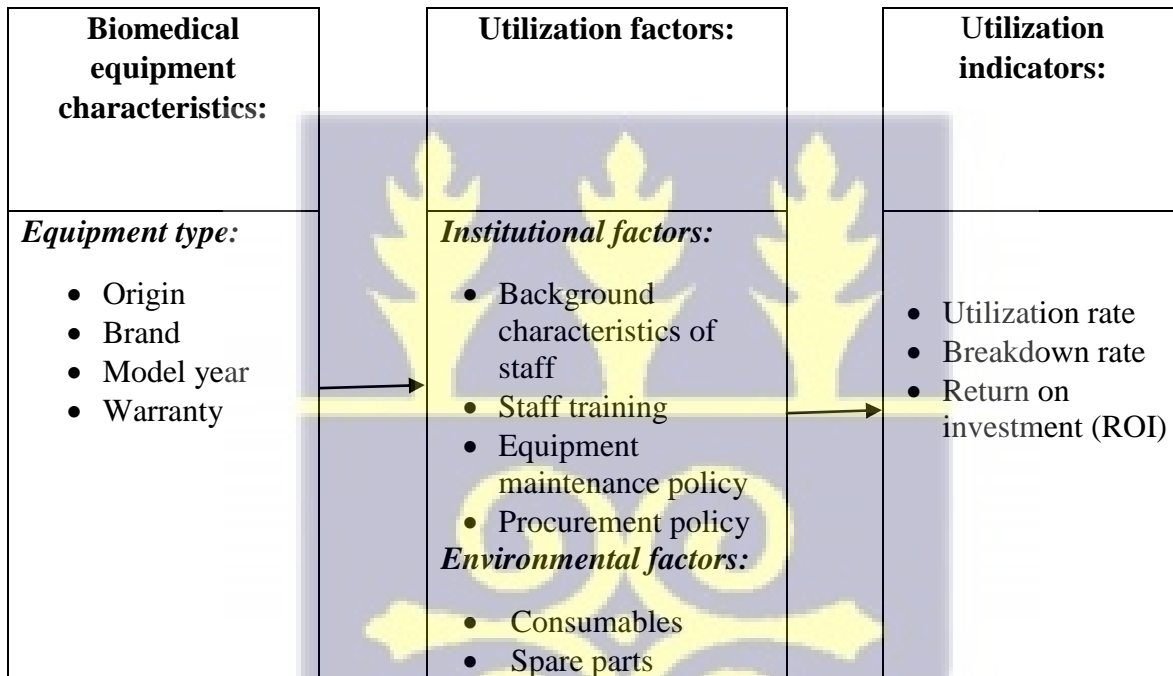


Figure 1: Conceptual framework for utilization of medical equipment



CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

This chapter focuses on the literature review on utilization of medical equipment in health facilities. The chapter has sub sections on utilization and breakdown rates of medical equipment. The chapter also reviewed literature on return on investment, characteristics and factors affecting utilization of Medical Equipment.

2.2 Healthcare Technologies and Quality of Care

Medical Equipment and Healthcare Technology (MEHT), which is a foundation of contemporary healthcare, is required to deliver a high level of care. Medical Equipment and Healthcare Technology's complicated system currently relies on a combination of planning, engineering, management, and financial expertise. Incorporating rapid technological advances through engineering methods and data is essential to providing high-quality healthcare. (Aragón & Garcia, 2015).

Medical Equipment and Healthcare Technology play an important role in the delivery of healthcare, such as illness prevention, quicker diagnosis, less intrusive treatment options, and shorter hospital stays and recovery times (Advanced Medical Technology Association, 2018). Medical Equipment and Healthcare Technology breakthroughs are reshaping the health-care environment, bringing novel medicines to patients with chronic conditions and altering how treatments are delivered. Medical technological advancements are helping to save lives. Its good

influence is not restricted to the social elite; it has also aided the poor by lowering child and mother death rates via the use of appropriate technology, such as incubators, and warmers (Sehgal, 2010).

2.3 Medical Equipment

Medical equipment is a crucial part of the healthcare system and is a tool used by clinicians in the recovery process after an accident or disease and in the detection, diagnosis, monitoring, and management of ailments. It might appear as a device, tool, program, appliance, or other item that the developer intended to be used either alone or in combination with other devices. (WHO, 2010). However, according to the WHO medical device technical series, the phrase "medical equipment" does not include implanted, disposable, or single-use medical devices (WHO, 2011). Calibrating, maintaining, fixing, instructing users in its usage, and finally decommissioning are all part of the lifecycle of medical equipment.

The health system's capacity to provide high-quality healthcare is hampered by a lack of medical equipment, either because it's unavailable or isn't working. According to the World Health Organization approximately 50 and 80% of medical devices in Low and Middle-Income Countries (LMICs) are non-operational, and that these nations lack technological evaluation processes and regulatory restrictions to stop the importation of low-quality medical equipment. By doing so, LMICs become vulnerable to unethical business tactics that endanger the lives of patients (WHO, 2012).

The caliber of the medical equipment has a significant impact on the efficacy of healthcare services. Healthcare institutions regularly have medical equipment failures or shortages, which has an influence on how well the general public is cared for. Poor management and maintenance of

the state of the medical equipment by the accountable party usually results in issues. Analyzing the condition of medical equipment during maintenance and life cycle management is essential to increase accessibility, productivity, and reliability. (Zamzam, Wahab, Azizan, Satapathy, Lai & Hasikin, 2021).

According to Zamzam et al, (2021), medical equipment reliability attributes can be classified into eight (8) categories including equipment features, operations, performance standards, risk and safety considerations, accessibility and responsiveness, usage, and cost. The reliability analysis completed for these eight characteristics will assist Bio-medical engineers when they carry out a planned maintenance operation that can boost the availability of the equipment, maintain performance, optimize resources, and ultimately contribute to offering the community efficient medical treatment..

2.4.0 Equipment Efficiency

Equipment efficiency is one of the issues that management often overlooks, which can result in losses by lowering production. Low diagnostic and therapeutic standards are the outcome of poor preventive maintenance of equipment., as well as an increase in the cost of equipment maintenance (Subramaniam, Husin, Yusop & Hamidon, 2019 and Jalali, Bahrani & Zeighami, 2016). The utilization index is one of the most essential criteria for monitoring the equipment's functioning state or evaluating the productivity of equipment servicing. Patient management and turnover will be optimized, with the lowest feasible cost, high-quality patient care, and patient satisfaction (IGNOU, 2010 and Hospital Equipment Utilization, 2008).

2.5.0 Equipment Utilization

Equipment utilization is the amount of time that the equipment is anticipated to function or is actually seen working. When a machine completes its scheduled machine hours (SMH) without any delays, the utilization is 100%, indicating that SMH and productive machine hours (PMH) are the same. Mathematically, utilization is calculated as a percentage usage rate by multiplying

the result of the division of PMH by SMH by 100. (that is $U = (PMH/SMH) \times 100$). If the usage coefficient is less than 50, the asset is deemed underused and hence a poor investment. Life-saving equipment, on the other hand, cannot be evaluated in this manner (Kumar, 2014).

According to Han & Han, (2020), the utilization rates for a processor is in the range of 45-50% as a result of inconsistent in yarder and processor production rates. Equipment utilization according to the current methods of estimating machine rates has a direct impact on hourly costs (\$/SMH and \$/PMH) as well as significant cost components including machine life and repair & maintenance (Zamora-Cristales, Sessions, Murphy, & Boston 2013).

According to Brinker, Kinard, Rummer, & Lanford, (2002) and Ackerman, Belbo, Eliasson, de Jong, Lazdins, & Lyons, (2014), The usual way for figuring out machine rates is to take the yearly straight-line depreciation of the machine that would have taken place during its planned life and prorate overall depreciation over the productive hours, raising the apparent rate of depreciation. The duration of the machine's service life remains constant, and so is the salvage value. Since yearly equipment depreciation rates are frequently correlated with rates of repairing and maintaining equipment, a rise in the depreciation rate may lead to an increase in these rates (Brinker et al., 2002). Exaggerated machine rates can distort comparisons of logging systems,

logging practices, equipment replacement strategies, and perhaps the profitability of a logging firm.

2.5.1 Equipment Life versus Utilization

Although equipment manufacturers frequently emphasize it, a piece of equipment's lifespan greatly relies on its operating environment and maintenance plan. For instance, Caterpillar offers recommendations (FAO, 2020) on equipment lifetimes that might differ by up to 50% or more depending on the operating conditions, therefore the initial choice is to pick the appropriate machine life taking the job to be done into consideration. Equipment wear and fuel consumption cease when it is shut off, regardless of the machine's lifespan. Fuel use and equipment wear continue when the machinery returns to its duty.

The equipment's life can be regarded as suspended when it is not in use. There may be certain exceptions, such as when equipment is susceptible to fast technical development and obsolescence, as in the electronics sector, or when it is prone to physical degradation due to prolonged storage. Recent improvements in Engine Idle Reduction Systems (EIRS) enable idle moment to be cut by up to 60%, even for brief durations. According to CAT (2020), prolonged periods of inactivity endanger component life, hasten the wear of Tier 4 technology (components for emissions treatment), necessitate unneeded fluid and filter replacements, exhaust warranty duration, and reduce resale value. Technologies like EIRS are being used more often.

Conventional machine rate estimates make the implicit assumption that depreciation never ceases, whether the machine is in use or not. The current machine rate calculation technique adjusts the depreciation per productive hour to match this and take into account the non-productive time. In essence, this says that equipment with a 50% utilization rate degrades in the same period of time

as equipment with a 100% utilization rate. (Sessions, Berry & Han, 2021). When used to its utmost, a machine with a 1% usage rate degrades in the same amount of time as a machine with a 100% usage rate. Ackerman et al. (2014) proposed a separate machine rate estimate for any accessories on expensive machines, such as the heads on processors and the cutting/processing heads on feller-bunchers, since they could be replaced at a different time than the carrier. Even though the engine on the carrier is functioning during non-productive time, there are some circumstances in which the hydraulic pumps, motors, rollers, cutting chains, and knives of the attachment are not functional. Therefore, regardless of the carrier's operation mode, wear on the attachment does not occur even when it is not being used.

The usable or economic equipment life of a machine is determined using machine rate models and is expressed in years. Other elements such as the total number of operating hours, have an intrinsic impact on machine rates (Brinker et al. 2002; Ackerman et al. 2014 and Bilek 2009. The United Nations' Food and Agricultural Organization (FAO) offers instructions on how to calculate machine rates emphasizing that rather than years, the economic life of agricultural equipment is sometimes calculated in terms of hours. (FAO 2020). The Caterpillar performance manual further supports this reasoning by stating that a crucial aspect in assessing operating and owning expenses is the total number of actual operating hours on a machine as well as the length of ownership (CAT, 2017).

2.5.2 Equipment Repair & Maintenance Cost versus Utilization Rate

In most cases, the hourly running time of machine parts is used to plan rebuilds or replacements. Although the machine rate models include the use of actual or expected repair and maintenance

costs, there are certain basic guidelines that relate equipment repair and upkeep expenses (\$/hr) to the amount of depreciation of the equipment (\$/hr) (Brinker et al, 2002). According to this logic, equipment depreciation measures how quickly an item's life is being utilized; the faster this happens, the more frequently an item requires repair and servicing.

On the other hand, machine rate models go a step further and calculate the entire service and repair expenses that would have occurred if the machine had been operated to its maximum capacity and divide that annual cost by the quantity of productive hours. (Brinker et al. 2002 and Ackerman et al. 2014). The end result is that the total predicted yearly maintenance cost for a machine with a 50% usage rate is equivalent to that of a machine with a 100% usage rate. When measured in terms of productive hours, the equipment that is 50% used has a repair and maintenance cost per productive hour that is twice as high as the unit that is 100% utilized. (Sessions et al., 2021).

2.6 Breakdown Rate

A crucial aspect of health care services is medical technology management. An efficient medical device strategy is required to assure excellent patient care (Derrico, Ritrovato, Nocchi, Faggiano, Capussotto & Franchin, 2011 and Miniati, Dori, Iadanza, Fregonara, & Gentili, 2011). A maintenance schedule created after taking the shortcomings of medical equipment into account is crucial to technology management (Sezdi, 2016). In a tertiary hospital setting, medical equipment accounts for nearly 40–50% of expenses. The equipment carries the danger of inevitable obsolescence within 6-7 years of installation even if it was state-of-the-art at the time of purchase (Chaudhary & Kaul, 2015). In a capital-intensive industry, maintenance costs often account for 40–50% of the operating budget. This number can be significantly decreased if sophisticated maintenance technology is made available. As a result, maintenance is sometimes the biggest single expenditure a company can manage (Mather, 2019).

Equipment downtime is the period of time that equipment is not in use, whether as a result of unforeseen equipment failure (such as a malfunction or broken part), or scheduled downtime needed to undertake preventive maintenance (www.upkeep.com). Research shows that a company loses \$260,000 on average for every hour when a machine is not working (The Aberdeen Group, 2016). Along with the revenue drop, there is also the matter of the wasted time and decreased staff productivity.

When an asset or piece of equipment is not in use, it is known as machine downtime (www.resco.net). There are 2 types of machine downtime:

1. Unplanned downtime – Mostly due to malfunction
2. Scheduled downtime – Essentially used for maintenance and repair

According to studies by Al-Bashir, Al-Tawarah & Jawwad (2017) on reducing medical equipment breakdown rate, failure rates attributable to mechanical and electrical causes were 42.3% and 22.6%, respectively. Hospitals must immediately consider ways to lower and better manage their maintenance expenditures (Fincher, 2019). According to research by the National Health Systems Resource Center, the malfunction rate for equipment may reach as high as 60% in different parts of the world, with rates averaging between 20 - 30% even in places with a little medical equipment sector presence (National Health Systems Resource Center, 2019). Maintenance not only benefits the security and efficacy of medical technology, but it also lengthens the equipment's lifespan and helps conserve scarce investment funds. The need for health services is also increased. Healthcare technology must be able to meet demand for services (Mutia, Kihui & Maranga, 2012)

2.7 Return on Investment

Return on Investment (ROI) is a financial tool that estimates the financial gains or returns from an investment (Botchkarew, 2015 and Gosselin, Boccanfuso & Laberge, 2020). The method for forecasting is known as ROI analysis. This technique converts (monetize) costs and benefits into ROI (Bukhari, Andreatta, Goldiez & Rabelo, 2017; Phillips, Phillips & Edwards, 2012 & Pokhrel, 2015). ROI is expressed as a percentage or a ratio, for instance., ROI = 1:1 indicates a 100% return. ROI is one of many financial metrics used to judge efficiency of an investment (Andru & Botchkarev, 2011).

According to ROI Parand, Dopson, Renz & Vincent, (2014) can be evaluated on its own, in contrast to other programs or in light of the counterfactual. Return on Investment has been utilized in the healthcare industry to assess the financial worth of a program after it has been put into place (Phillips *et al.*, 2012). ROI has also been applied in business as a way to gauge how well product quality requirements are being met (Otake & Min, 2001)]. It is occasionally utilized as a performance management tool, to make sure that organizations reach their targeted strategic goals (Hewko & Cummings, 2016).

2.8 Medical Equipment Characteristics

Features of the equipment are collection of traits that were created specifically for it and have been there ever since it was produced. Age is one of the criteria used to assess the state of medical equipment (Kovacevic *et al.*, 2019). The age of the equipment is a good indicator of its general condition. This is equipment normally performs better when at an early age and mostly have minimal faults. The equipment starts to deteriorate as it becomes old. The brand of the equipment

and its mode of operation are two additional criteria that were taken into consideration when assessing dependability (Badnjević et al., 2019 and Kovacevic et al., 2019). When assessing the equipment condition for the Replacement Programme (RP) prioritization, one of the input criteria previously employed was the service availability (Faisal & Sharawi (2015). The warranty, documentation, instruction, and appropriate replacement parts are all included in the service availability of the medical equipment. Studies by Saleh, Sharawi, Elwahed, Petti, Puppato, & Balestra, (2015) and Saleh & Balestra, (2015) included equipment complexity as a factor in analysis of the dependability of medical devices.

2.9 Factors affecting Medical Equipment Utilization

Staff training, policy for managing medical equipment, procurement policy, and environmental factors have all been recognized as factors that influence medical equipment utilization (Guyow et al., 2021). Equipment installations done in turnkey projects and the working schedule of the hospital have also been identified as factors which could affect utilization of medical equipment (Pandit & Unadkat, 2017)

2.9.1 Staff Training Policy

Various human resource difficulties, such as employee training and motivation, have hampered the success of medical equipment usage. The training should include how to operate medical equipment as well as ongoing skill updates on how to enhance the technologies employed in the medical equipment (Mutia, Kihiu, & Maranga, 2012 and Fulmer & Ployhart, 2014). The perspective and experience of medical facility users have an influence on the use of hospital devices. (Umunna, 2012). In addition, the study found that the degree and adequacy of the staff training had an impact on the use of medical equipment.

2.9.2 Medical Equipment Maintenance Policy

Medical equipment purchases, usage, and disposal have a considerable impact on the quality of health services provided to patients (Mutia et al's. 2012). The medical equipment management policy should direct management and health care managers throughout the life cycle of medical equipment, including the acquisition, use, upkeep, and sale of medical equipment, as well as the provision of operation manuals, training for biomedical technicians, and provision of necessary spare parts (Douglas & Connor, 2003 and Kirui, Luciani, Ochieng & Kamau, 2013). According to Ademe, Tebeje, & Molla (2016), medical equipment consumption is impacted by a lack of maintenance, excessive use, the purchase of unnecessary gadgets, and insufficient training on how to use the medical equipment. Medical equipment that was not regularly maintained was susceptible to failure (Bahreini, Doshmangir, & Imani, 2018). According to Suji & Vaanmathi (2020), utilization rate is impacted by a lack of strategic planning in the management of medical equipment, especially with regard to the acquisition of equipment at the suitable time, location, and with the appropriate maintenance agreement.

2.9.3 Procurement Strategy

Needs, stakeholder participation, and quality supplies must all be factors in a comprehensive medical equipment procurement strategy. Medical hospitals are confronted with challenges of purchasing medical equipment based on needs and disposing them. This procurement approach leads to medical supply obsolescence, overstocking, understocking, and expiry. (CSCMP, 2016).

It has been found that expensive equipment built on a turnkey basis is used more effectively since the business ensures that aspects like civil, electrical, and air conditioning installation are taken into account while planning the equipment (Pandit & Unadkat, 2017). As a result, the equipment

is completely operational when it is delivered to the hospital. Staff are mostly trained in advanced by the installation company prior to the facility's inauguration.

2.9.4 Working Hours

Working hours of hospital have also been identified as a factor that can affect the utilization of medical equipment (IGNOU, 2010). The hospital's work schedule should be planned so that the expensive equipment is used to its fullest potential. In most government hospitals especially for the specialized clinics such as ENT and Eye, the equipment is only used for 8 hours per shift, or 33% of the time (Pandit & Unadkat, 2017). High-cost machinery might only be used for 50–60% of its capacity if these facilities are made available for two shifts.

2.9.5 Environmental Factors

Medical equipment, like other electronics, are subjected to a variety of environmental stresses, including power supply stability, temperature, and humidity (Siti Hajar et al. 2019). These stressors can cause a variety of failure mechanisms, which, depending on the device design and use, can render the medical device unusable, render it incapable of providing the therapy as intended, or jeopardize the user's safety.

More so, technology in the healthcare industry is sometimes hampered by the absence of dependable power and water (Johns & El-Nageh, 2000). Some equipment is made to work with an electrical and water infrastructure that is already in place (Elnageh & Houang, 1993). It is occasionally necessary to have access to distilled, deionized water. Hospitals in LMICs hardly ever have reliable, continuous access to power (Malkin, 2007).

2.10 Conclusion

The literature review covered: (i) Healthcare Technologies and Quality of care; (ii) Medical Equipment; (iii) Equipment Efficiency; (iv) Equipment Utilization; (v) Breakdown rate; (vi) Return on Investment; (vii) Medical Equipment characteristics and (viii) Factors affecting Medical Equipment.

The various literature reviewed indicate importance of medical equipment and how the utilization of these medical equipment are affected by the equipment characteristics, institutional and environmental factors. Few studies have however highlighted the utilization indicators and return on investment especially in public health facilities. This study would help bridge the knowledge gaps and ultimately help in the effective and efficient utilization of medical equipment.



CHAPTER THREE

3.0 METHODS

This chapter provides an overview on the methods to be used in the study. The elements covered comprised study design, study area, study population, study variables, eligibility criteria, estimation of study sample size, sampling procedures, data collection techniques/tools, data processing, quality control, and data analysis.

3.1 Study design

A cross-sectional study design with quantitative data collection method which utilized data extraction and surveys.

3.2 Study area

The research was conducted at the Nkenkaasu Government Hospital, a district hospital with 51 bed capacity. It is in Offinso North district. It provides in-patient and out-patient services. Owing to its location on Kumasi -Techiman highway, it serves as a major referral point for emergencies.

Within the period under review (January, 2022 to September, 2022), the hospital recorded a total expenditure of Ghc1,701,263.21. The hospital spent GHc86,454.23 on general maintenance and out of this figure a total of GHc15,042.25 was spent on maintenance of equipment. An amount of GHc47,700 was used to procure new equipment to replace broken down or malfunctioning equipment. Table 1 summarizes the background characteristics of Nkenkaasu Hospital.

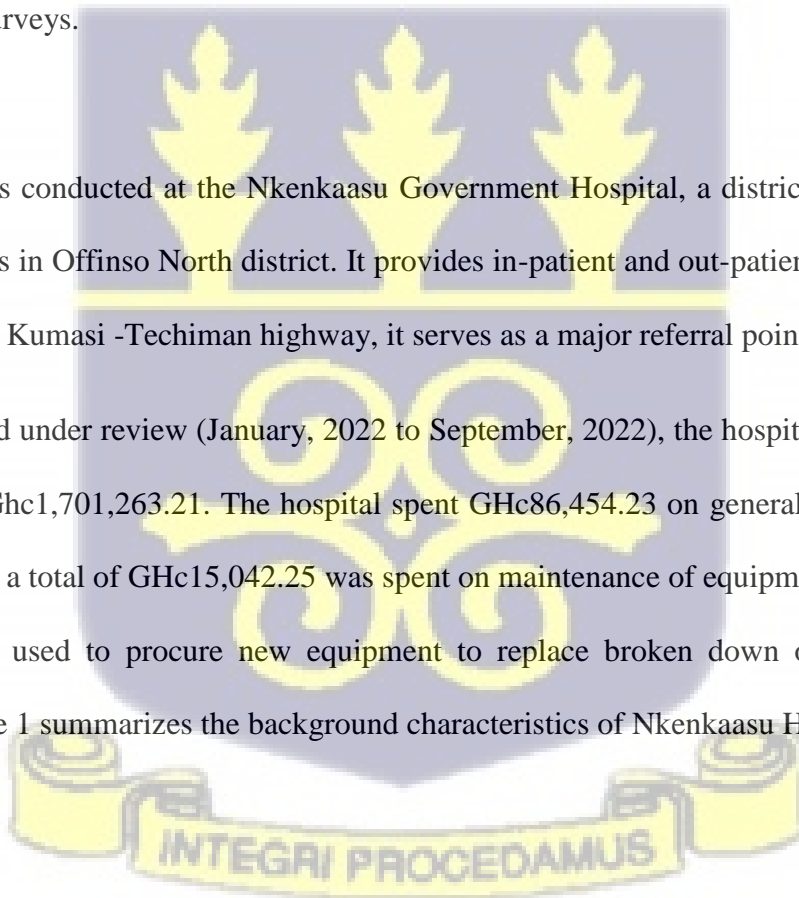


Table 1: Background characteristics of Nkenkaasu Government Hospital

Characteristics	Responses
Type of health facility	District Hospital
Total hospital bed capacity	51
Total expenditure	Ghc1,701,263.21
Total general expenditure on maintenance	GHC86,454.23
Total expenditure for equipment maintenance	GHC15,042.25
Total expenditure on procurement of new equipment	GHC47,700

(Third Quarter Performance Review Report (2022) Nkenkaasu Government Hospital).

3.3 Study population

Different kinds of medical devices (total of 45) in 6 functional units/ department of the hospital were used for the study. The functional areas were chosen because they were areas where clinical services were provided. These areas included Out-Patient Department, In-patient Wards, Theatre, Laboratory, Maternity and Emergency Unit.

The study population also included health care personnel who use, handle, and maintain the medical equipment. Medical personnel who used the medical equipment were included in the study population and they comprised of Medical Doctors, Nurses, Midwives, Laboratory Staff, Peri-operative nurses and Physician Assistants

3.4 Study variables

Table 2 shows the study variables of the study.

Table 2: Description of study variables

Type of Variable	Variable
Dependent	1.Utilization rate 2.Break down rate 3. Return on investment
Independent	1.Characteristics of medical equipment 2. utilization factors

3.5 Eligibility criteria

3.5.1 Inclusion criteria

The inclusion criteria of the study were:

1. Staff who have been working with biomedical equipment (BE).
2. All selected biomedical equipment.

3.5.2 Exclusion criteria

The exclusion criteria of the study were:

1. Staff working with BE but not willing or unavailable at the time of the study
2. Selected BE which is broken down or malfunctioning at the time of the study

3.6 Estimation of study sample size

The study covered purposively selected 45 medical equipment in the various functional units of Nkenkaasu Government Hospital according to Global Health Compendium (www.appropedia.org). A census was conducted to identify staff who were willing to participate in the study as shown in table 3.

Table 3: Details of Respondents

No	Respondents Designation	Number
1	Medical Officers	2
2	Peri-operative Nurses	2
3	Nurses/ Midwives	81
4	Laboratory staff	12
5	Physician Assistant	1
	Total	98

A complete list of medical equipment was prepared and assessed from the different functional departments of the hospital as shown in table 4.



Table 4: List of medical equipment in the various functional units

No	Equipment	Brand	Model Year	Warranty	Quantity of each equipment	Country of origin	Total Equipment per country
1	Anaesthesia machine	Drager	*	One year	1	China	22
2	Blood Bank Fridge	BioBase	*	One year	1		
3	Blood Pressure monitor	Accuson	*	No	2		
4	Haemoglobin meter	URIT	*	No	3		
5	Microscope	Olympus	*	One year	1		
6	Nebulizer	Fazzini	*	No	1		
7	Oxygen concentrator	New Life	*	One year	1		
8	Patient monitor	Mindray	*	One year	1		
9	Pulse oximeter	Konsung	*	No	5		
10	Thermometer	Greetmed	*	No	2		
11	Water bath	Jactermac	*	No	1		
12	Weighing scale	Camry	*	No	3		
13	Blood Pressure monitor	Omron	*	No	1	Vietnam	1
14	Centrifuge	800D series	*	No	1	Japan	4
15	Haematology analyzer	Sysmex	*	One year	1		
16	Ultrasound scan	Toshiba	*	One year	1		
17	Water distiller	Waterwise	*	No	1		
18	Delivery bed	Promek	*	One year	1		
19	Electrophoresis machine	Bio System (Bioreader)	*	No	1	Spain	2
20	Hot air oven	Selecta	*	No	1	Australia	2
21	Fetoscope	Sonicaid	*	No	1		
22	Nebulizer	Chempro	*	No	1	France	1
23	Surgical operating bed	Blanco med	*	One year	1		
25	Patient bed	Metallic	*	One year	4	Canada	4
26	Nebulizer	Beper	*	No	1	Italy	2
27	Suction machine	Atmos	*	No	1		
28	Glucometer	Easy Touch	*	No	1	Korea	1
29	Oxygen concentrator	Drive	*	One year	1	USA	4
30	Stethoscope	Littman	*	No	2		
31	Weighing scale	Wasing	*	No	1		
32	Theatre lamp	Brandon	*	One year	1		
	Total	-	-	-	45		45

* = data not recorded in the Asset Register

3.7 Data collection techniques/tools

In collecting the data for this study, the following data collection techniques were used:

1. Data extraction
2. Interviews

Various utilization records of the department including purchase files, asset registers, log books, and service records of individual medical diagnostic equipment was also reviewed. The interviews were conducted in Nkenkaasu Government Hospital and they were expected completed within a period of two (2) weeks. All available staff in the various units were interviewed using a questionnaire. The interview questions used the 5-point Likert-scales to assess the perception of respondents on factors affecting utilization. The interviews were conducted by Research Assistants and supervised by the Principal Investigator with guidance from the academic thesis supervisor and the GHS ethics review committee.

3.8 Data processing

The completed data extraction sheets and questionnaires were edited and checked for completeness and consistency by supervisors. Checked data extraction sheets and questionnaires were aligned to the specific objectives of the study for analysis.

3.9 Quality control

Training of field staff: The data collectors were trained on the goals of the study as well as how to approach and manage questions for a period of 2 days.

Revision of data collection tool: Necessary changes were made to the data collection tool after the pretest.

Supervision of fieldwork: The data collectors were closely supervised by the Principal Investigator

Data coding and entry: Data was checked for completeness and consistency.

3.10 Data Analysis

3.10.1 Determination of background characteristics of respondents

The respondents' characteristics were obtained by cross tabulating sex with education level, staff category and years of service.

3.10.2 Estimation of utilization rate of medical equipment

The Utilization co-efficient is a way of determining the functionality of equipment and is calculated using Kumar (2014) approach:

Mathematically, utilization is calculated as a percentage usage rate by multiplying the result of the division of Productive Machine Hours (PMH) by Scheduled Machine Hours (SMH) by 100. (that is Utilization co-efficient (UC) = (PMH/SMH) x 100).

$$(UC) = (A \times B/C \times D) \times 100$$

where:

,"A" is the number of days the medical diagnostic equipment was actually used during the period of June, 2022. It is measured in hours.

"B" is the number of working hours the equipment was actually used for (average procedure time divided by average number of operations carried out each working day).

"C" represents how many days the medical devices may have been accessible (if the equipment was put in working order). It is measured in hours.

"D" represents how many working hours the medical diagnostic equipment may have been accessible (if the equipment was put in working order).

The utilization co-efficient of each piece of equipment was computed separately using the method above. If the co-efficient is less than 50%, the equipment was deemed to be underutilized, and vice versa. The only exemption to this type of analysis is lifesaving medical equipment.

3.10.3 Estimation of breakdown rate of medical equipment

The study used the following approach to estimate the breakdown rate of medical equipment:

1. Identify the planned operating time for a set period.
2. Record the amount of downtime for the month or consult a report from the previous month if you have one.

The formula (ManagerPlus, 2021) used was:

$$\text{Breakdown Rate} = \text{Time equipment is down} / \text{Planned operating time} * 100$$

3.10.4 Estimation of Return on Investment of medical equipment

Estimation of the Return on Investment of the medical equipment was done using Julie (2017) approach:

1. Implementation Cost includes the following
 - a. Cost of equipment

- b. Running cost (training of staff, consumables and accessories procured, cost of utilities used)
- c. Maintenance Cost of equipment

2. Total Revenue

The formula used was:

Return on Investment = Net Returns/ Implementation Cost

That is = $\frac{\text{Total Revenue} - \text{Implementation Cost}}{\text{Implementation Cost}}$

The Return on Investment was only estimated for haematology analyzer, microscope, and ultrasound scan since they were used individually to provide direct healthcare. The rest of the medical equipment were components of the health service, thus making it difficult to segregate their Return on Investment.

3.10.5 Determination of utilization factors of medical equipment

The analysis of the independent variables of medical equipment was descriptive using 5-point Likert scale. Utilization factors will be assessed. The Likert scale used had five points: (1) Strongly disagree, (2) Disagree, (3) Neutral, (4) Agree and (5) Strongly agree to measure utilization factors of training, maintenance policy, working hours, procurement, humidity, power stability, temperature, consumables, and spare parts. The responses were tabulated and presented in frequencies, percentages, graphs, and tables. The scores for each of the domain of utilization factors were used to describe the domain. The scores for each domain's summation were added and re-classified. This was used to determine the effect of utilization factors on medical equipment.

A logistic regression was done to determine the significant factor driving utilization of medical equipment.

Table 5a: Determination of utilization factors among Staff

No.	Domain	Dimension	Score Range
1	Training	1. Strongly disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly agree	2-10
2	Equipment Maintenance Policy	1. Strongly disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly agree	4-20
3	Procurement Policy	1. Strongly disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly agree	1-5
4	Working Hours	1. Strongly disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly agree	2-10
5	Environmental Condition	1. Strongly disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly agree	5-25
6	Availability of consumables/ Spare parts	1. Strongly disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly agree	2-10
	Total		80
	Range		16 - 80

- 1 Scores estimated from 2 questions by 5 responses = 10
- 2 Scores estimated from 4 questions by 5 responses = 20
- 3 Scores estimated from 1 questions by 5 responses = 5
- 4 Scores estimated from 2 questions by 5 responses = 10
- 5 Scores estimated from 5 questions by 5 responses = 25
- 6 Scores estimated from 2 questions by 5 responses = 10

3.10.6 Composite utilization score among staff

The composite utilization score was obtained through summation of the responses in each domain and multiplying them by the number of questions. The total score was aggregated and classified into three dimensions, Low, Moderate and High utilization with their corresponding ranges of 16-37, 38-59 and 60-80 respectively using the descriptive tertile statistic approach as indicated in the Table 5b below.

Table 5b: Composite Utilization score among staff

No	Dimension	Range
1	Low	16 – 37
2	Moderate	38 – 59
3	High	60 – 80

3.11 Ethical consideration

The Ethical approval for the study was sought from the Ghana Health Service Ethics Review Committee (GHS-ERC: 031/10/22).

Permission was obtained from the Medical Superintendent of Nkenkaasu Government Hospital.

Consent was also sought from all participants.

3.12 Limitation of study

The study limitations were:

1. The study was limited to 45 biomedical equipment used in hospitals because they were the very critical devices that keep the service running.
2. The estimation of some of the utilization indicators was limited to a period of one (1) month due to uncertainty about the availability and reliability of some of the hospital data for study.
3. The Return on Investment was only estimated for haematology analyzer, microscope and ultrasound scan since they were used individually to provide direct healthcare. The rest of the medical equipment were components of the health service, thus making it difficult to segregate their Return on Investment.



CHAPTER FOUR

4.0 RESULTS

4.1 Background characteristics of staff

Table 8 shows background characteristics of the staff. About 63.3% (62) were females and 76.5% (75) had diplomas. About 82.7% (81) were nurses/midwives and about 84.7% (83) had worked for less than 10 years.

Table 6: Background characteristics of Staff

Variable	Category	Frequency	Percentage (%)
Sex	Male	36	36.7
	Female	62	63.3
Education level	Diploma	75	76.5
	Bachelors	23	23.5
Profession	Nurses/ Midwives	81	82.7
	Laboratory Staff	12	12.2
	Physician Assistant	1	1.0
	Peri-Operative Nurse	2	2.0
	Medical Doctors	2	2.0
Duration of work (years)	Less than 10 years	83	84.7
	Over 10 years	15	15.3
	Total	98	100

4.2 Utilization rate of biomedical equipment

Table 9 shows utilization rate of the biomedical medical equipment. About 23% (6) of the equipment were fully utilized and they included equipment such as microscope, haematology analyzer and fetoscope. About 23% (6) of the equipment such as BP monitor, patient and delivery beds were moderately utilized. About 54% (14) of the equipment such as suction machine, patient monitor and anaesthesia machine were underutilized.

Table 7: Utilization rate of biomedical equipment

	Equipment	Utilization rate (%)	Interpretation	Total Utilization (%)
1	Microscope	100	Full utilization	23.1 (6)
2	Hot air oven	100	Full utilization	
3	Haematology Analyzer	100	Full utilization	
4	Fetoscope	100	Full utilization	
5	Centrifuge	100	Full utilization	
6	Blood bank	100	Full utilization	
7	BP monitor*	88	Partial utilization	23.1 (6)
8	Weighing scale*	88	Partial utilization	
9	Patient Bed*	82	Partial utilization	
10	Thermometer*	75	Partial utilization	
11	Delivery bed	65	Partial utilization	
12	Stethoscope*	52	Partial utilization	
13	Patient monitor*	48	Low utilization	53.8 (14)
14	Nebulizer*	38	Low utilization	
15	Oxygen concentrator*	35	Low utilization	
16	Ultrasound scan	33	Low utilization	
17	Anesthesia machine	33	Low utilization	
18	Water distiller	30	Low utilization	
19	HB meter	25	Low utilization	
20	Theatre lamp	16	Low utilization	
21	Surgical operating bed	16	Low utilization	
22	Water bath	13	Low utilization	
23	Patient Monitor	13	Low utilization	
24	Glucometer	13	Low utilization	
25	Suction machine	4	Low utilization	
26	Electrophoresis machine	4	Low utilization	

* = Utilization rate for equipment located in more than one department

4.3 Utilization rate of biomedical equipment per department

Table 8 shows the average utilization rate of the biomedical medical equipment in each of the department. Pulse oximeter recorded the highest utilization rate of 67% in theatre while patient bed and weighing scale recorded 100% utilization rate in the emergency department. Laboratory equipment such as blood bank fridge, centrifuge, haematology analyzer, hot air oven and

microscope showed 100% utilization rate. Fetoscope, patient bed and weighing scale recorded 100% utilization rate in the maternity department. Equipment such as BP monitor and weighing scale showed 100% utilization in both the Out-Patient department and in patient wards.

In all medical equipment in the Out Patient Department recorded the highest utilization rate of 100%. Medical equipment in the theatre however showed the least utilization rate of 39.1%.

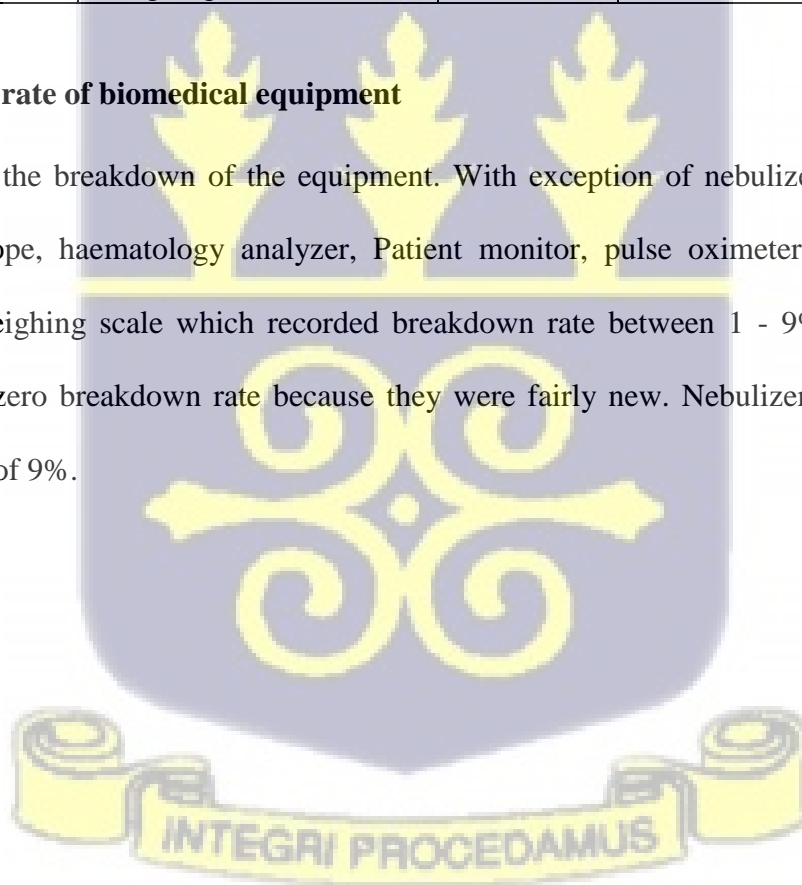
Table 8: Utilization rate of biomedical equipment per department

No	Department	Equipment	Utilization rate (%)	Average utilization rate (%)
1	Theatre	Anesthesia machine	33	39.1
		Patient Bed	64.5	
		Pulse Oximeter	67	
		Surgical operating bed	15.5	
		Theatre lamp	15.5	
2	Laboratory	Blood bank fridge	100	58.5
		Centrifuge	100	
		Electrophoresis machine	4	
		Glucometer	13	
		Haematology analyzer	100	
		HB meter	25	
		Hot air oven	100	
		Microscope	100	
		Water bath	13	
		Water distiller	30	
3	Maternity	Delivery bed	65	67.8
		Fetoscope	100	
		Nebulizer	44.5	
		Oxygen concentrator	50	
		Patient bed	100	
		Thermometer	50	
		Ultrasound scan	33	
		Weighing scale	100	
4	Outpatient Department	BP monitor	100	100
		Pulse Oximeter	100	
		Stethoscope	100	
		Thermometer	100	

		Weighing scale	100	
5	Emergency	BP monitor	63	42.3
		Nebulizer	17	
		Oxygen concentrator	21	
		Patient Bed	100	
		Patient monitor	13	
		Pulse Oximeter	20	
		Suction machine	4	
		Weighing scale	100	
6	In-patient Wards	BP monitor	100	52.3
		Nebulizer	18	
		Patient bed	100	
		Pulse Oximeter	42	
		Stethoscope	4	
		Weighing scale	50	

4.4 Breakdown rate of biomedical equipment

Figure 2 shows the breakdown of the equipment. With exception of nebulizer, blood pressure monitor, fetoscope, haematology analyzer, Patient monitor, pulse oximeter, ultrasound scan machine and weighing scale which recorded breakdown rate between 1 - 9%, the rest of the equipment had zero breakdown rate because they were fairly new. Nebulizers had the highest breakdown rate of 9%.



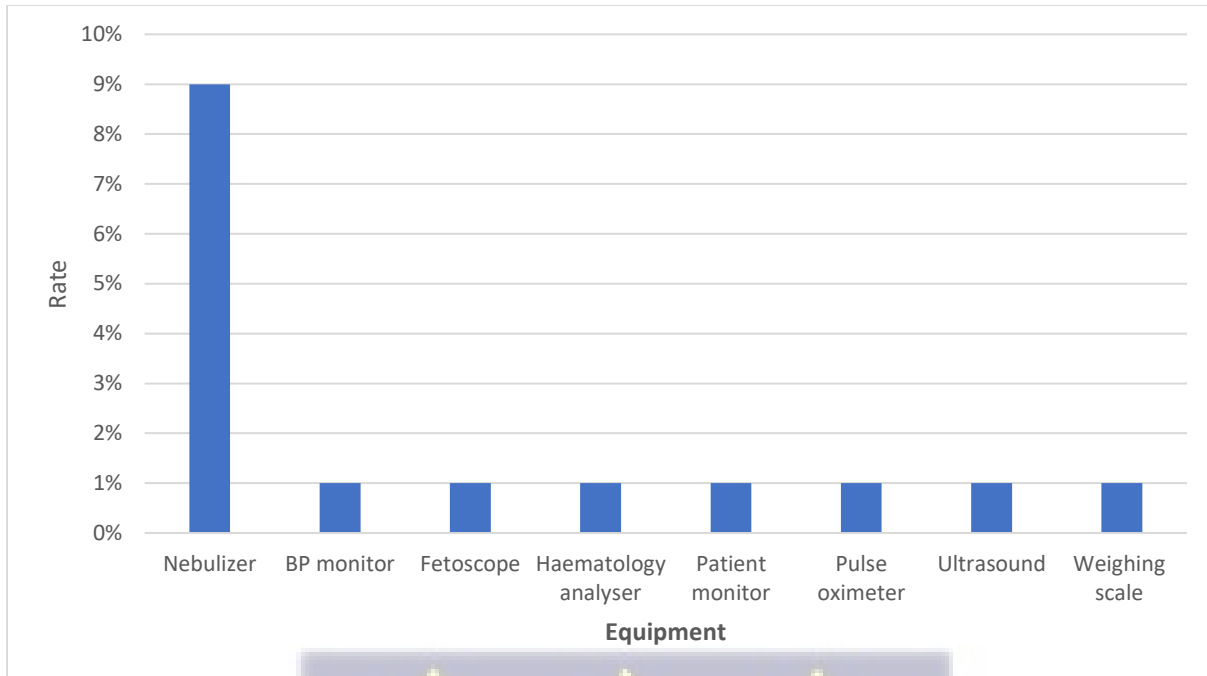


Figure 2: Breakdown rate of biomedical equipment

4.5 Return on investment

Return on investment on only three (3) medical equipment namely microscope, haematology analyzer and ultrasound scan machine were estimated due to unavailability of required data. Apart from these equipment which can work in isolation to produce a direct health service, all the others work with other devices to produce a health service, thus making it difficult to compute their return on investment.

Overall, it will take a period of 3 years and 3 months for haematology analyzer to break even. It would also take a period of 11 months and 4 years and 9 months for microscope and ultrasound scan machine to break even respectively.

4.6 Utilization factors associated with biomedical equipment among the staff

Figure 3 shows the utilization factors associated with biomedical equipment among the staff. Procurement policy, working hours and environmental conditions were found to be dominant utilization factors.

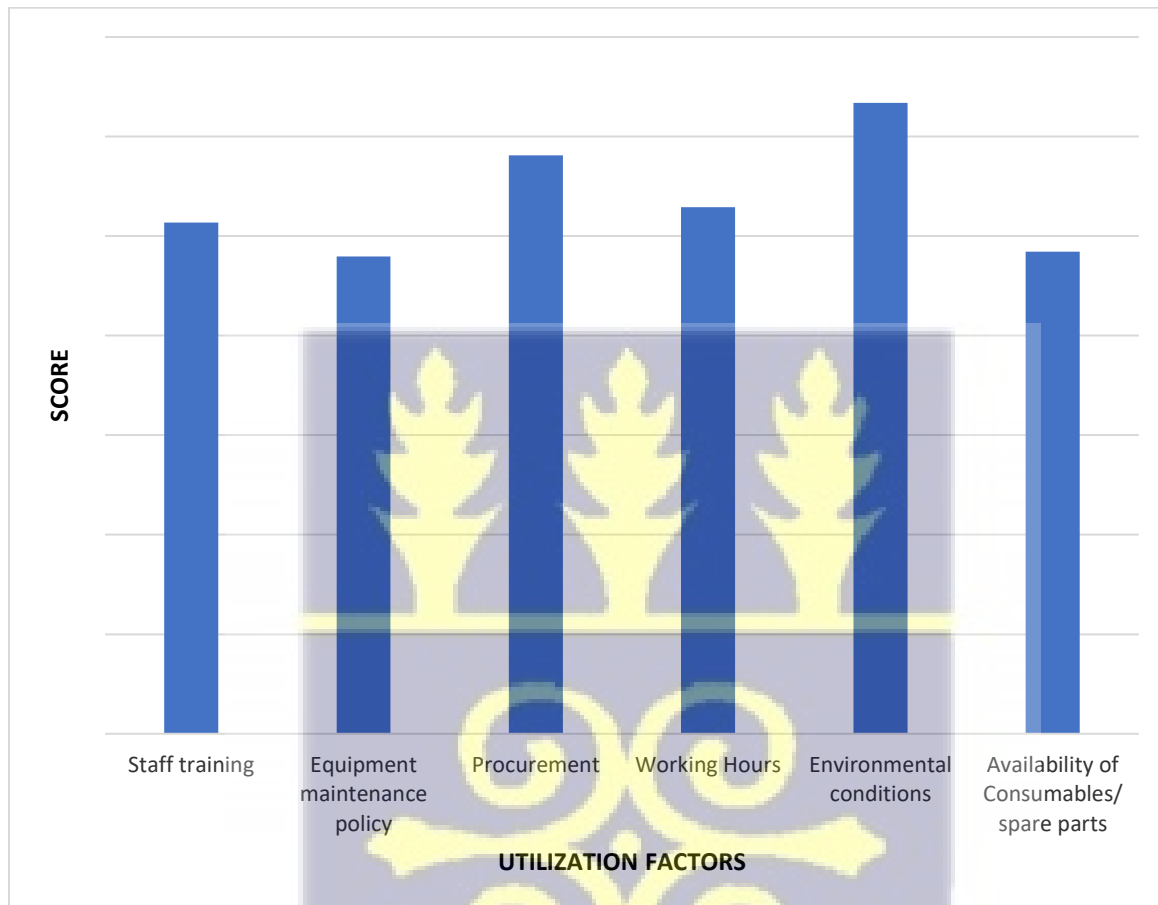


Figure 3: Utilization factors associated with biomedical equipment among the staff

Table 9 shows detailed analysis of factors driving utilization of medical equipment in Nkenkaasu Government Hospital. From Table 9, the rate of breakdowns of equipment as a component of working hours was found to be statistically significant at 5% significant level.

Table 9: Factors associated with utilization of medical equipment

Utilization rate	Odds Ratio.	St.Err.	t-value	p-value	[95% Conf Interval]	Sig
Socio-demographic information:						
Sex: base 1	0	.	.	.	.	.
2	6.423	3.868	1.66	.101	-1.279 14.125	
Education level: base 1	0	.	.	.	.	.
2	-2.686	4.842	-0.55	.581	-12.328 6.955	
Professional grade	-1.473	2.165	-0.68	.498	-5.785 2.838	
Years of practice	.255	.434	0.59	.559	-.609 1.119	
Staff Training:						
Staff trained upon receipt of new equipment	-1.364	2.582	-0.53	.599	-6.505 3.777	
Availability of scheduled training	1.951	2.617	0.75	.458	-3.259 7.162	
Equipment maintenance policy:						
Servicing of equipment at least once a year	1.037	1.961	0.53	.599	-2.868 4.941	
Equipment are in good condition	2.425	1.987	1.22	.226	-1.531 6.382	
Availability of equipment logbooks	3.434	2.04	1.68	.096	-.629 7.497	*
Availability of reference manuals	-3.76	2.101	-1.79	.078	-7.944 .425	*
Procurement policy:						
	.145	2.007	0.07	.943	-3.851 4.141	
Working hours:						
Rate of breakdown of equipment	3.31	1.622	2.04	.045	.08 6.539	**
Rate of servicing broken down equipment	1.663	1.899	0.88	.384	-2.119 5.445	
Environmental conditions:						
Availability of back-up power supply	-1.816	2.018	-0.90	.371	-5.835 2.202	
Availability of voltage stabilizers	-.878	1.894	-0.46	.644	-4.65 2.894	
Suitability of temperature	1.617	2.293	0.71	.483	-2.948 6.182	
Workplace safety and health	-.864	2.175	-0.40	.692	-5.195 3.467	
Adequacy of water supply	-2.688	1.821	-1.48	.144	-6.314 .938	
Availability of consumables/ spare parts:						
Availability of consumables	-.445	2.265	-0.20	.845	-4.954 4.064	
Availability of spare parts	-1.548	2.235	-0.69	.491	-5.997 2.902	
Constant	55.457	10.752	5.16	0	34.047 76.868	
Mean dependent var		59.544	SD dependent var		16.363	
R-squared		0.289	Number of obs		98	
F-test		1.566	Prob > F		0.084	
Akaike crit. (AIC)		833.486	Bayesian crit. (BIC)		887.770	

 *** $p < .01$, ** $p < .05$, * $p < .1$

4.7 Other factors that influence equipment utilization

Factors like availability of logbooks, staff training and voltage stabilizers affected utilization as shown in Table 10. About 72.4% of staff were not aware of any equipment training schedule. It means that staff are not trained when new equipment are acquired and there exist no refresher training to update staff knowledge on the use of the equipment. About 81.6% were not aware of the use of equipment logbooks in the hospital. About 68.4% of them were not aware about the availability of voltage stabilizers for the equipment.

Table 10: Other factors that influence equipment utilization (in %)

Question	Aware	Not aware
Training of staff upon acquisition of new equipment	27.6	72.4
Availability of training schedule	19.5	72.5
Availability of logbooks	18.4	81.6
Availability of voltage stabilizers for equipment	31.6	68.4

As shown in Table 4, about 66.7% (30) of the equipment did not have warranties at the time of procurement because they were no indication of such in the facility's equipment file. Those with warranties were for a period of one year. About 48.9% (22) of the equipment were from China. All the equipment had various brand names. However, data on the model year was not available because it was not recorded in the Asset Register.

CHAPTER FIVE

5.0 DISCUSSION

The study revealed that on average 53.8% of the equipment were underutilized. Utilization got affected due to a number of days wasted due to breakdown or any other reason. The most affected was nebulizer which recorded the highest breakdown rate of 9% and had a utilization rate of 38%. The microscope showed the quickest return on investment of 11 months. Working hours had a significant relationship with utilization.

5.1 Utilization rate of biomedical equipment

Utilization index is one of the critical indicators used to measure the functional status of equipment (IGNOU, 2010). Full utilization of equipment will increase the returns on the investment and improve patient satisfaction. Utilization of equipment can be classified into three types namely full utilization, partial utilization and underutilization based on the use co-efficient. Full utilization occurs when the use co-efficient is 100%, partial utilization is when the use co-efficient is $\geq 50\%$ but less than 100% and underutilization happens when the use co-efficient is $< 50\%$.

About 53.8% of the equipment had use coefficients of less than 50% and these mostly comprised of life-saving and surgical equipment such as oxygen concentrator, nebulizer, anesthesia and suction machines. Having a use co-efficient of $< 50\%$ is underutilized and hence a bad investment (Kumar, 2014). This finding is similar to WHO estimates that about 50% of medical equipment in developing countries is not functioning and not optimally used and high-quality life-saving medical devices are not accessible in most of health facilities in Africa (Health Technologies, 2003). This finding is also like research conducted in a Dental Institution in Bengaluru, India by Gupta *et. al*, (2017) which indicated that about 50% of medical equipment was underutilized. The

result is however dissimilar to study conducted in the Department of Histopathology, Chandigarh, India by Chaudhary & Kaul, (2014) which found average utilization coefficient of medical equipment to be 60.2%. This is not surprising because the study was conducted in a tertiary hospital setting where there could be increased demand for service due to referrals. A further reading of the research showed that most of these equipment in the Department were procured as per the needs and demands stated by the various departments of the hospital. Lack of structured procurement and maintenance systems are factors of ineffective equipment utilization.

For the purposes of efficiency, limited amount of the underutilized equipment can be procured to be shared among the various units/ departments. This will help to reduce associated indirect cost such as cost of maintenance and electricity. Alternatively, the management of the hospital can network with other health facilities in the district to optimize utilization rate of these devices. Also, the hospital management can develop marketing strategy to promote the services to the community. All these measures can help boost the utilization of these equipment and ultimately optimize the benefits of these capital investments.

The study also revealed that about 23.1% (6) of the biomedical equipment were fully utilized. This equipment included microscope, hot air oven, haematology analyzer and fetoscope. The rest of the equipment were centrifuge and blood bank fridge. They are used to conduct routine diagnostic examinations in health facilities. The blood bank fridge for example is expected to be working all the time to maintain cold chain of blood products, hence they are expected to be fully utilized. Conversely, life-saving and surgical equipment showed the lowest utilization rate. Suction machines had the lowest utilization rate of 4% unlike microscope which recorded a utilization rate of 100%. Equipment such as microscopes and haematology mostly form the core of routine

diagnostic investigations conducted in primary hospitals and because of that they are highly utilized and this could account for the observation.

The utilization rate of Hb meter is 25% even though determination of hemoglobin concentration is a routine laboratory test conducted in most health facilities. This is because the hematology analyzer is mostly used in laboratory settings to measure Hb concentration (De Rosa & Roederer, 2001; Lau, Lee & Chan, 2008). The Hb meter can alternatively be used in situations when the hematology analyzer is not available. Therefore, when the utilization rate for hematology analyzer is high, it is likely the use of HB meter will be low.

Equipment such as electrophoresis machine, suction machine recorded the lowest utilization rate of 4%. A suction machine for example is primarily used for removing obstructions like mucus, blood and other secretions from a person's airway. Such an activity is not a routine activity in most hospital setup, thus the low utilization rate.

Glucometer, patient monitor and water bath recorded a utilization rate of 13%. Water bath which is mostly used to conduct a Glucose-6-phosphate dehydrogenase (G6PD) test is expected to record low utilization rate because it is not a routine test but essential test conducted for pregnant women once in their lifetime. The only surprising equipment in the list is glucometer because they formed core of the routine diagnostic investigations conducted in most health facilities. Glucometer is used to determine the concentration of glucose in the blood for management of both hypoglycemic and hyperglycemic disorders (Tonyushkina & Nichols, 2009). In the era of increasing chronic conditions, most hospital have established hypertension and diabetes clinics to prioritize and effectively manage these conditions. The use of glucometers is expected to be high especially in a hospital setting. The utilization rate of this device is probably low in the laboratory department

because the hospital might have different diagnostic points for testing glucose level of patients. Otherwise, the hospital may have to investigate this observation.

5.2 Utilization rate of biomedical equipment per department

Equipment in the Outpatient Department (OPD) recorded a utilization rate of 100% and it implied full and efficient utilization of these equipment as compared to equipment used in other departments. The Working hours have also been identified as a factor that can affect the utilization of medical equipment (IGNOU, 2010). The OPD which operates 24 hours is mostly the first point of call during hospital visit and highly patronized department of the hospital. These devices are used to take vital signs of clients for the purposes of triaging and this could account for the observed full utilization rate.

The level of the hospital and the services it provides could affect the utilization rate of some of the equipment. If the facility is a referral facility or tertiary hospital, the utilization rate for some of these life saving devices would be high as compared to a primary hospital. Likewise, district hospitals with limited referrals and surgical interventions are likely to underutilize these lifesaving and surgical equipment.

5.3 Breakdown rate of biomedical equipment

About 8 equipment recorded breakdown rates, the rest of the equipment were fairly new and had zero breakdown rate. It was realized that the government of Ghana had retooled most of the hospitals with equipment such as oxygen concentrators, patient beds and microscope during the peak of the Covid-19 pandemic and Nkenkaasu Government Hospital was a beneficiary. Some of the old and malfunctioning equipment had been replaced and this possibly accounted for the observed zero breakdown rate. In addition, the zero-breakdown rate could be due to

implementation of planned preventive maintenance system by the management of the health facility. Planned preventive maintenance of equipment helps to reduce downtime and optimize the use of the equipment.

Moreover, utilization got affected due to several days wasted due to break down or any other reason. The most affected was nebulizer which recorded the highest breakdown rate of 9% and had a utilization rate of 38%. Similar reason could be cited for ultrasound scan which recorded a utilization rate of 33% yet formed a significant core of primary diagnostic investigations conducted in health facilities.

There is the need to further conduct breakdown analysis to ascertain what could be accounting for the observation. However, about 72.4% of the staff were not aware of any equipment training schedule. Also, about 67% indicated that equipment did not have voltage stabilizers. Previous studies on equipment downtime by Al-Bashir et al. (2017) attributed 42.3% and 22.6% of failure rates to mechanical and electrical causes. It is possible that some of the observed breakdown rate could be due to manual errors and electrical issues. Regular training of the end users and procurement of voltage stabilizers are recommended for the purposes of ensuring efficiency and optimizing the use of these devices.

5.4 Return on investment

The microscope showed the quickest return on investment of 11 months and this was not so surprisingly. Microscopes are used to conduct routine laboratory investigations such as blood film tests, routine urine analysis and sickling test and are usually in high demand. It means microscope is a high performing item both in utilization and return on investment. The facility might consider

buying more of this item but otherwise it is running efficiently. However, there are no published documents to support this assertion.

5.5 Utilization factors associated with biomedical equipment among staff

The study also identified the factors affecting utilization of medical equipment. Break down rate of equipment, which is a component of working hours is the only independent variable that had a statistically significant relationship with utilization at 5% significant level. An increase in working hours will increase the utilization rate by 3.31%. Similar studies by Chaudhary and Kaul (2015) in China also showed similar results.

The study was limited to 45 biomedical equipment. Estimation of the utilization indicators of this equipment was limited to one month because of some level of uncertainty in the availability and reliability of data. It was however realized that about 80% of the department were not using equipment logbooks and this made it quite challenging to assess the performance records of these equipment. The absence of equipment logbooks might have contributed to some of the observations.

Features of equipment such as model year (age) are significant factors for assessing the performance of equipment (Kovacevic et al., 2019). Age of equipment can contribute to equipment downtimes and efficiency. Some devices are idle because of the difficulty in procuring its spare parts or accessories on the market. It was however difficult to ascertain the age of the equipment because the asset register was not comprehensively updated. Moreover, most of the equipment was not procured with warranties except those that were donated by the Ministry of Health in partnership with donor agencies. The warranties covered a period of one year. The need for the

Hospital Management to ensure these devices are procured with warranties cannot be overemphasized owing to the expensive nature of these equipment.

Working hours have been found as a key determinant of equipment utilization. Routine equipment mostly recorded high utilization rates as compared with life-saving equipment. The hospital management should ensure medical equipment is well maintained to improve their utilization rate and return on investment.



CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATION

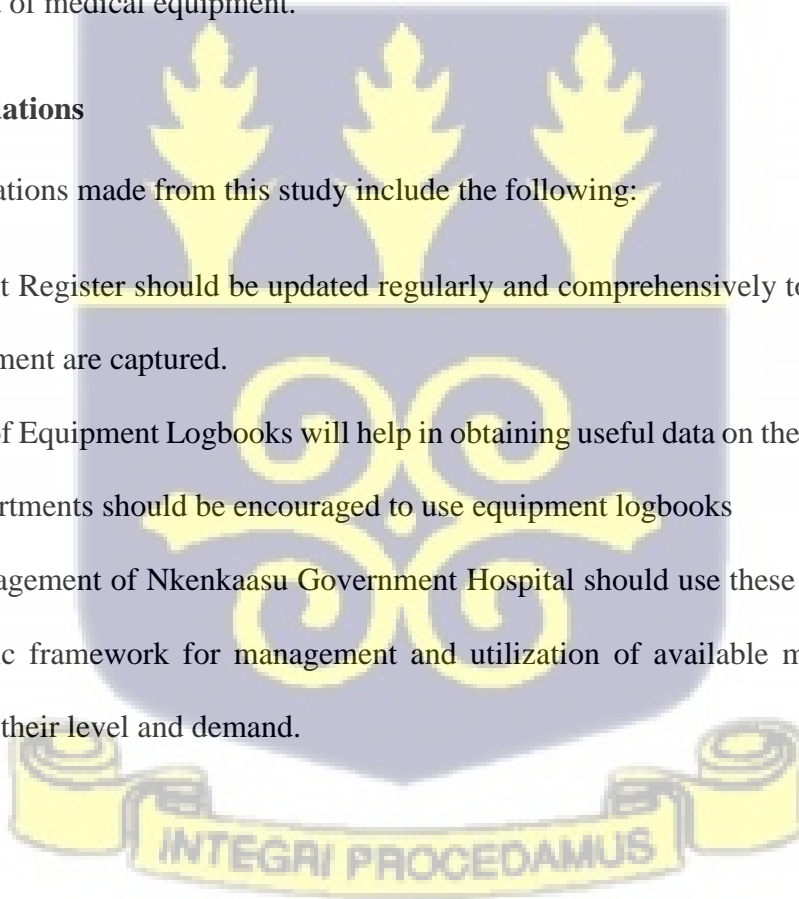
6.1 Conclusion

Estimation of utilization of medical equipment in a health facility is crucial for procurement planning. Utilization of these equipment is also affected by the factors such as working hours. Malfunctioning or broken-down equipment can affect the delivery of quality healthcare and return on investment. The study has drawn attention to how these huge investment in the health sector can be used optimally. The health facility should use the results of the study to improve the use and management of medical equipment.

6.2 Recommendations

The recommendations made from this study include the following:

- i. The Asset Register should be updated regularly and comprehensively to ensure details of all equipment are captured.
- ii. The use of Equipment Logbooks will help in obtaining useful data on the use of equipment. The departments should be encouraged to use equipment logbooks
- iii. The management of Nkenkaasu Government Hospital should use these results to develop a strategic framework for management and utilization of available medical equipment based on their level and demand.



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APPENDICES

APPENDIX A: PARTICIPANTS INFORMATION SHEET

Title of Study: Assessment of biomedical equipment utilization in Nkenkaasu Government Hospital, Ashanti Region

Introduction:

Dear Participant:

My name is Agyenim Collins Boateng, the Principal Investigator of this study and a Master of Health Economics student of the School of Public Health, University of Ghana, Legon

Find below my contact details:

P.O Box 5743, Adum Kumasi

Email: abcyllins@hotmail.com

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Background and Purpose of research: The research assesses biomedical equipment utilization in health facilities.

Nature of research: Biomedical Equipment are expensive capital items acquired by health facilities either through donation or procurement to enhance the delivery of health service. There is a little evidence to show how facilities are utilizing these equipment.

The research seeks to find the utilization rate and breakdown rate of these biomedical equipment. Some of the equipment would be selected for assess their return on investment. The study will be done in Nkenkaasu Government Hospital. Utilization records of the hospital biomedical equipment will be assessed. Staff of the hospital will also be interviewed.

Participants involvement:

- **Duration /what is involved:** Participants will be given questionnaires on equipment utilization to answer.
- **Potential Risks:** The study holds minimal risk to the study participants.
- **Benefits:** There are no direct benefits for taking part in this study.
- **Cost:** The study does not come with any form of cost to the participants
- **Compensation:** There will be no compensation for participants in this study
- **Confidentiality:** The privacy and confidentiality of the participants and information they provide would be strictly adhered to. Interview instrument sheets will be completed and sent directly into a database without it being accessed by any third

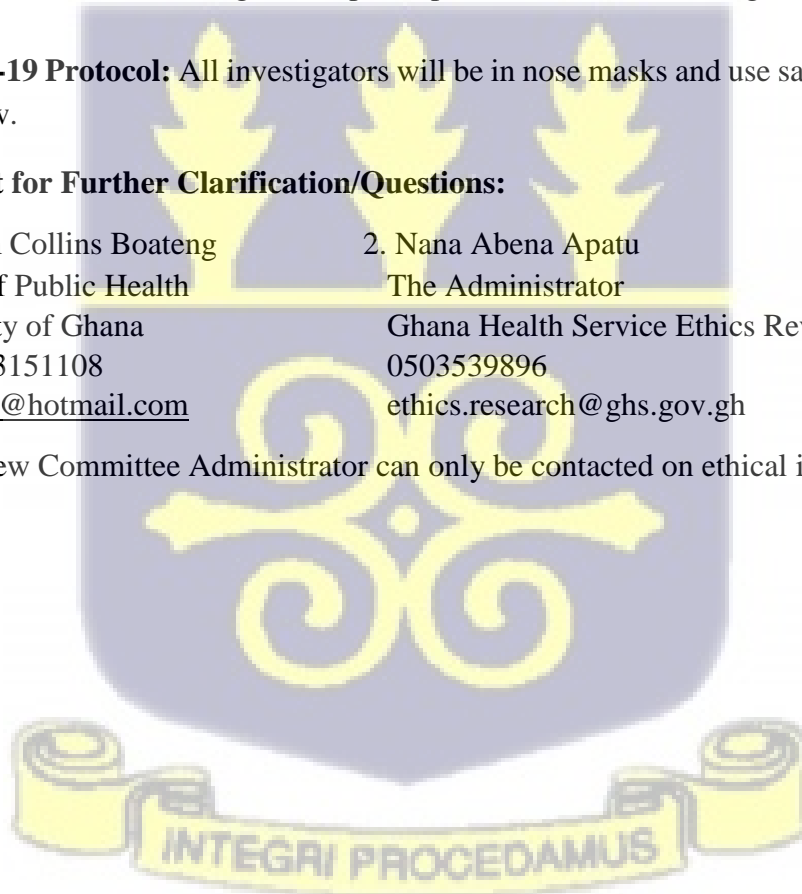
party. The questionnaire will not even request respondents' names or residence addresses, phone numbers, etc to ensure anonymity.

- **Voluntary participation/withdrawal:** Participants would voluntarily enter the study and would have the liberty to exit at any point in time without penalty and without having to give any reasons.
- **Outcome and Feedback:** The data obtained in this study will be used for the stated purposes and outcome will also be shared with the various stakeholders in this study.
- **Feedback to participant:** Participants will be given feedback in a form of email.
- **Funding information:** The study is funded by the World Health Organization.
- **Sharing of participants Information/Data:** Hard and soft copies of the data would be stored in a locked file cabinet with limited access to the Principal Investigator and Supervisor.
- **Provision of Information and Consent for participants:** A copy of the Information sheet and Consent Form will be given to participants after it has been signed or thumb printed to keep.
- **COVID-19 Protocol:** All investigators will be in nose masks and use sanitizers during the interview.

Who to Contact for Further Clarification/Questions:

- | | |
|--|--|
| 1. Agyenim Collins Boateng
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University of Ghana
+233-243151108
abcyllins@hotmail.com | 2. Nana Abena Apatu
The Administrator
Ghana Health Service Ethics Review Committee
0503539896
ethics.research@ghs.gov.gh |
|--|--|

The Ethics Review Committee Administrator can only be contacted on ethical issues



APPENDIX B: CONSENT FORM

STUDY TITLE: Assessment of biomedical equipment utilization in Nkenkaasu Government Hospital, Ashanti Region

PARTICIPANTS' STATEMENT

I acknowledge that I have read or have had the purpose and contents of the Participants' Information Sheet read and all questions satisfactorily explained to me in a language I understand (English, Twi). I fully understand the contents and any potential implications as well as my right to change my mind (i.e. withdraw from the research) even after I have signed this form.

I voluntarily agree to be part of this research.

Name of Participant.....

Participants' SignatureOR Thumb Print.....

Date:.....

INTERPRETERS' STATEMENT

I interpreted the purpose and contents of the Participants' Information Sheet to the afore named participant to the best of my ability in the (English, Twi) language to his proper understanding.

All questions, appropriate clarifications sort by the participant and answers were also duly interpreted to his/her satisfaction.

Name of Interpreter.....

Signature of Interpreter OR Thumb Print

Date:.....

Contact Details

STATEMENT OF WITNESS

I was present when the purpose and contents of the Participant Information Sheet was read and explained satisfactorily to the participant in the language he/she understood (English, Twi)

I confirm that he/she was given the opportunity to ask questions/seek clarifications and same were duly answered to his/her satisfaction before voluntarily agreeing to be part of the research.

Name:.....

Signature..... OR Thumb Print

Date:.....

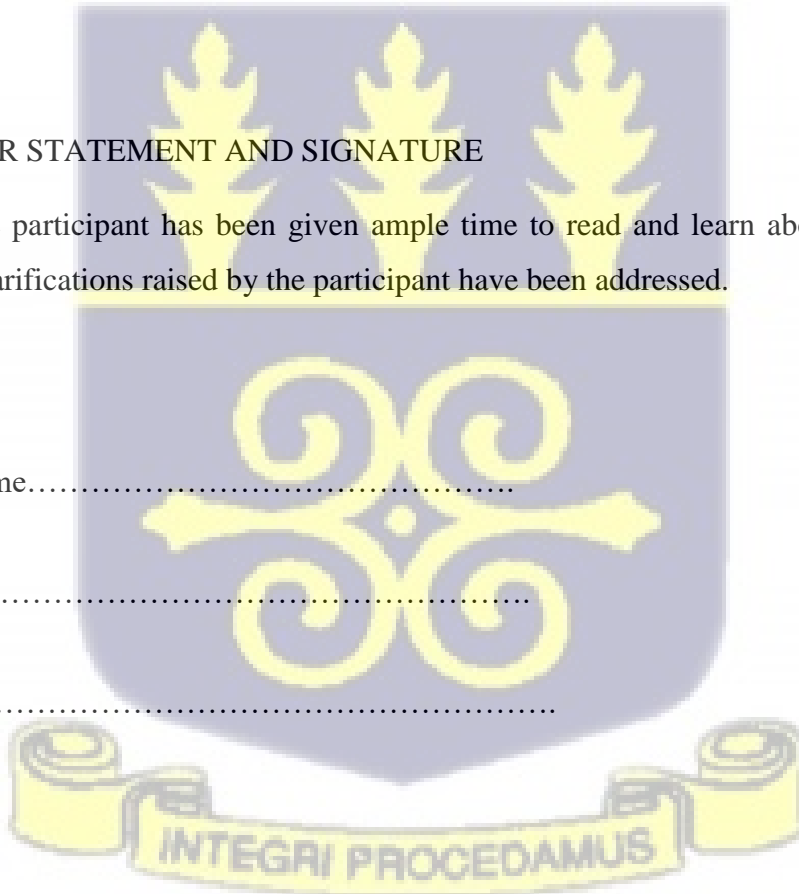
INVESTIGATOR STATEMENT AND SIGNATURE

I certify that the participant has been given ample time to read and learn about the study. All questions and clarifications raised by the participant have been addressed.

Researcher's name.....

Signature

Date.....



APPENDIX C: QUESTIONNAIRE

**ASSESSMENT OF MEDICAL EQUIPMENT UTILIZATION IN NKENKAASU
GOVERNMENT HOSPITAL, ASHANTI REGION**

Utilization factors associated with medical equipment.

(To be completed by Staff)

Qn No	Questions	Response
		Respondent ID: <input type="text"/> <input type="text"/> <input type="text"/>
Section 1	Socio-demographic Information	Please indicate the appropriate number in the box
1	What is your sex 1. Male 2. Female	<input type="checkbox"/>
2	What is the highest level of school attended? 1. Diploma 2. Degree 3. Masters	<input type="checkbox"/>
3	What is your profession? 1. Nurses/ Midwives 2. Laboratory Staff 3. Physician Assistant 4. Anaesthetist 5. Peri-Operative Nurse 6. Medical Doctors	<input type="checkbox"/>
4	How many years have you practiced the profession above?	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> Years
Section 2	Staff Training	Responses (Please indicate the appropriate number in the box)
5	The hospital provides training to us whenever we receive new equipment 1. Strongly Disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly Agree	<input type="checkbox"/>

6	<p>The Hospital has scheduled trainings to update staff knowledge on use of equipment</p> <ol style="list-style-type: none"> 1. Strongly Disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly Agree 	<input type="checkbox"/>
Section 3 Equipment Maintenance Policy		
7	<p>All equipment are serviced at least once a year</p> <ol style="list-style-type: none"> 1. Strongly Disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly Agree 	<input type="checkbox"/>
8	<p>All equipment are in good condition at the moment</p> <ol style="list-style-type: none"> 1. Strongly Disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly Agree 	<input type="checkbox"/>
9	<p>Logbooks are available to use for all equipment</p> <ol style="list-style-type: none"> 1. Strongly Disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly Agree 	<input type="checkbox"/>
10	<p>The manuals of equipment are available for referencing</p> <ol style="list-style-type: none"> 1. Strongly Disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly Agree 	<input type="checkbox"/>
Section 4 Procurement Policy		
11	<p>Procurement of equipment is done based on need assessment</p> <ol style="list-style-type: none"> 1. Strongly Disagree 2. Disagree 3. Neutral 4. Agree 	<input type="checkbox"/>

	5. Strongly Agree	
Section 5	Working Hours	
12	Equipment frequently breaks down in your department/ Unit 1. Strongly Disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly Agree	<input type="checkbox"/>
13	When equipment breakdown, they are repaired within specified period 1. Strongly Disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly Agree	<input type="checkbox"/>
Section 6	Environmental Condition	
14	The hospital has a back-up power supply 1. Strongly Disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly Agree	<input type="checkbox"/>
15	The equipment has voltage stabilizers to save it from damage 1. Strongly Disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly Agree	<input type="checkbox"/>
16	My working Laboratory/ unit/ office has suitable temperature for the equipment 1. Strongly Disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly Agree	<input type="checkbox"/>

17	<p>My workplace is generally safe and healthy</p> <ol style="list-style-type: none"> 1. Strongly Disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly Agree 	<input type="checkbox"/>
18	<p>My working Laboratory/ unit/ office has adequate water supply</p> <ol style="list-style-type: none"> 1. Strongly Disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly Agree 	<input type="checkbox"/>
Section 7	Availability of consumables/ Spare parts	
19	<p>Consumables for operating the equipment is readily available</p> <ol style="list-style-type: none"> 1. Strongly Disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly Agree 	<input type="checkbox"/>
20	<p>Equipment spare parts is readily available</p> <ol style="list-style-type: none"> 1. Strongly Disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly Agree 	<input type="checkbox"/>

THANK YOU FOR YOUR COOPERATION AND PARTICIPATION



**ASSESSMENT OF MEDICAL EQUIPMENT UTILIZATION IN NKENKAASU
GOVERNMENT HOSPITAL, ASHANTI REGION**

Utilization rate, break down rate and return on investment of medical equipment

(To be completed by Heads of Department and Estates Manager)

Qn No.	Questions	Response
Respondent ID: <input type="text"/> <input type="text"/> <input type="text"/>		
Section	Details on Equipment	Please provide the appropriate response in the box
1	Name of equipment	
2	Purpose of equipment	
3	Name of department/ Unit 1. Laboratory 2. OPD 3. Maternity 4. Theatre 5. Emergency 6. Wards (Adult and Paediatrics)	<input type="checkbox"/>
4	Country of origin	
5	Year of manufacture	
6	Availability of equipment for use 1. Always 2. Specific timings 3. On request/ permission	<input type="checkbox"/>

Objective 1	Estimation of Utilization Rate	Response
7	Number of working days in a week	<input type="text"/>
8a	On average, what is the working hours per day?	<input type="text"/>
8b	Do you have the same hours for each working day? 1. Yes 2. No	<input type="checkbox"/>
8c	If no, what is the minimum working hour per month?	<input type="text"/>
9a	How many days in your working week is the equipment accessible?	<input type="text"/>
9b	Are the working days the same throughout the month? 1. Yes 2. No	<input type="text"/>
9c	If no, how many days is the medical equipment accessible in a month?	<input type="text"/>
10a	On average, how many hours is expected for the medical equipment to be accessible in a day if put in good use?	<input type="text"/>
10b	Are the expected hours same for each working day in a month? 1. Yes 2. No	<input type="checkbox"/>
10c	If no, what is the minimum expected working hours in a month?	<input type="text"/>

Objective 2	Estimation of Breakdown Rate	Response
11a	Do you have planned operating period set for this equipment? 1. Yes 2. No	<input type="checkbox"/>
11b	If yes, what is the period within a month?	<input type="text"/>
11c	If no, what is the estimated period?	<input type="text"/>
12	In the last month for this equipment, what was the number of days the equipment was down?	

Objective 3	Estimation of Return on Investment	
13	What is the purchasing cost of equipment	<input type="text"/>
14a	What is the cost of consumables used by the equipment after acquisition.	<input type="text"/>
14b	What is the total cost of utilities used by the equipment within the last 6 months?	
14c	What is total cost incurred to train staff on the use of the equipment after acquisition?	
15	What is the total maintenance cost incurred to keep the equipment functional?	<input type="text"/>
16	What is the total revenue (both NHIS and out of pocket) received from the use of the equipment during the period	<input type="text"/>

Thank you for your cooperation and participation

Appendix D: Return on investment for haematology analyzer

	YEAR 1	YEAR 2	YEAR 3	YEAR 4
Revenue	86,976.30	95,673.92	105,241.32	115,765.45
Expense				
Initial cost	89,000.00			
Running Cost	44,688.15	49,156.96	49,156.96	49,156.96
Maintenance	17,800.00	19,580.00	19,580.00	19,580.00
Training Cost	1,500.00		1,500.00	
Total expense	151,488.15	68,736.96	68,736.96	68,736.96
Net Cash Flow	(64,511.85)	26,936.96	36,504.35	47,028.49
Discount Factor	1.00	1.00	1.00	1.00
Discounted Cash Flow	(64,511.85)	26,936.96	36,504.35	47,028.49
	(64,511.85)	(37,574.89)	(1,070.53)	0.27
Payback Period	1year	2years	3years	3.27years



Appendix E: Return on investment for microscope

	YEAR 1
REVENUE	32,135.70
Expense	
Initial cost	16,590.00
Running Cost	7,427.14
Maintenance	3,318.00
Training Cost	1,500.00
Total expense	28,835.14
Net Cash Flow	3,300.56
Discount Factor	1.00
Discounted Cash Flow	3,300.56
Payback period	10.8 months



Appendix F: Return on investment for ultrasound scan


	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
Revenue	26,721.71	29,393.89	32,333.27	35,566.60	39,123.26
Expense					
Initial cost	63,180.00				
Running Cost	5,508.26	6,059.08	6,059.08	6,059.08	6,059.08
Maintenance	12,636.00	13,899.60	13,899.60	13,899.60	13,899.60
Training Cost	2,000.00				2,000.00
Total expense	81,324.26	19,958.68	19,958.68	19,958.68	19,958.68
Net Cash Flow	(54,602.54)	9,435.20	12,374.59	15,607.92	19,164.58
Discount Factor	1.00	1.00	1.00	1.00	1.00
Discounted Cash Flow	(54,602.54)	9,435.20	12,374.59	15,607.92	19,164.58
	(54,602.54)	(45,167.34)	(32,792.75)	(17,184.83)	0.90
Payback Period	1year	2years	3years	4year	4years 9months



Appendix F: GHS-ERC Approval letter

GHANA HEALTH SERVICE ETHICS REVIEW COMMITTEE

In case of reply the number and date of this Letter should be quoted.



My Ref: GHS/RDD/ERC/Admin/App/22/511
Your Ref. No.

Research & Development Division
Ghana Health Service
P. O. Box MB 190
Accra
Digital Address: GA-050-3303
Mob: +233-50-3539896
Tel: +233-302-681109
Email: ethics_research@ghs.gov.gh
2nd November, 2022

Collins Boateng Agyenim
P.O. Box 5743
Adum - Kumasi, Ghana

The Ghana Health Service Ethics Review Committee has reviewed and given approval for the implementation of your Study Protocol.

GHS-ERC Number	GHS-ERC: 031/10/22
Study Title	Assessment of Biomedical Equipment Utilization in Nkenkaasu Government Hospital, Ashanti Region
Approval Date	2 nd November, 2022
Expiry Date	1 st November, 2023
GHS-ERC Decision	Approved

This approval requires the following from the Principal Investigator


- Submission of a yearly progress report of the study to the Ethics Review Committee (ERC)
- Renewal of ethical approval if the study lasts for more than 12 months.
- Reporting of all serious adverse events related to this study to the ERC within three days verbally and seven days in writing.
- Submission of a final report after completion of the study
- Informing ERC if study cannot be implemented or is discontinued and reasons why
- Informing the ERC and your sponsor (where applicable) before any publication of the research findings.

You are kindly advised to adhere to the national guidelines or protocols on the prevention of COVID -19

Please note that any modification of the study without ERC approval of the amendment is invalid.

The ERC may observe or cause to be observed procedures and records of the study during and after implementation.

Kindly quote the protocol identification number in all future correspondence in relation to this approved protocol



SIGNED.....
Dr. Nasir Korkor Alotey
(Ag. Head, Ethics & Research Management Department)

Cc: The Director, Research & Development Division, Ghana Health Service, Accra