



## Exploring life cycle costing as a tool for sustainable procurement of medical equipment; A case study of selected federal healthcare institutions in Enugu State

Okafor Mirabel<sup>1</sup>, Philip Dahida<sup>2</sup>, Ibrahim Musa<sup>3</sup>

<sup>1</sup> Sustainable Development center, University of Abuja, Abuja, Nigeria

<sup>2</sup> Department of Public Administration, University of Abuja, Abuja, Nigeria

<sup>3</sup> Department of Economics, University of Abuja, Abuja, Nigeria

### Abstract

This study examined the use of Life Cycle Costing (LCC) as a tool for sustainable procurement of medical laboratory equipment, specifically Biochemistry Analyzers, in selected federal healthcare institutions in Enugu State, Nigeria. Despite growing recognition of sustainable procurement, Nigerian healthcare institutions often neglect comprehensive lifecycle evaluations, resulting in suboptimal investment decisions, higher long-term costs, and compromised patient care. Using a mixed-method approach, the research surveyed 273 procurement professionals, biomedical engineers, and laboratory scientists and conducted 30 key informant interviews. Quantitative analysis applied Net Present Value (NPV) methods to five years of procurement data, comparing open- and closed-system Biochemistry Analyzers. Results showed that open systems, though costlier initially, offered superior financial sustainability, lower lifecycle costs, earlier payback periods, and greater operational flexibility. The study also revealed a significant awareness-practice gap: while LCC concepts were well known, practical application was limited, particularly regarding disposal costs, environmental impacts, and residual values. Key barriers included insufficient lifecycle data, limited technical expertise, inadequate policy frameworks, and cultural resistance. The study recommends institutionalizing LCC through comprehensive policies, targeted capacity building, robust data management, structured procurement tools, leadership advocacy, and stakeholder engagement. Overall, the findings underscore that LCC adoption enhances financial efficiency, sustainability, and alignment with global standards, contributing to resilient healthcare procurement systems.

**Keywords:** Life cycle costing, sustainable procurement, medical equipment and federal healthcare institutions

### Introduction

The procurement of medical equipment plays a decisive role in health facilities' ability to deliver safe, reliable, and cost-effective care. In many low- and middle-income countries (LMICs), procurement decisions are often driven by lowest-upfront-cost criteria, donor offers, or immediate availability rather than full consideration of longer-term operational, maintenance, and disposal costs (life-cycle costs). Such procurement practices can lead to frequent equipment downtime, higher total expenditures over the asset's life, and service delivery interruptions (IISD, 2010; THET, 2017). Understanding procurement through a life-cycle lens is therefore critical for ensuring that scarce resources translate into sustained clinical benefit.

Life Cycle Costing (LCC) is a decision-support methodology that quantifies all relevant costs of an asset over its entire life span, acquisition, installation, operation, maintenance, and end-of-life disposal, often expressed as present-value sums to allow direct comparison between alternatives (ISO, 2017). LCC differs from simple purchase-price comparison by explicitly incorporating future cash flows, replacement and maintenance schedules, energy and consumable use, training, and decommissioning costs, making it well-suited to evaluate medical technology whose lifetime costs frequently exceed purchase price. International standards and guidance (e.g., ISO 15686-5; IISD guidance) provide structured approaches and common terminology that improve transparency and robustness in LCC analyses.

In the context of medical equipment, applying LCC can uncover the true economic and operational trade-offs

between competing devices (for example, cheaper single-use solutions versus more expensive reusable systems), reveal the cost impact of spare-parts logistics and local maintenance capacity, and steer procurement toward options that minimise total system costs while supporting clinical objectives (Chang, 2022; Mang *et al.*, 2023)<sup>[4, 19]</sup>. Studies in hospital settings have shown that LCC approaches can improve tender evaluation, reduce unplanned downtime, and align procurement with sustainability goals (e.g., reduced energy or disposal costs), but adoption remains uneven because of capacity constraints, limited lifecycle data, and procurement rules focused on initial price.

Despite the clear theoretical benefits of LCC, empirical evidence on its adoption and effectiveness in many Nigerian public health institutions is limited. Studies examining equipment procurement and management in Nigerian radiology and other clinical departments have documented inconsistent procurement procedures, poor maintenance planning, and high rates of non-functional equipment problems that LCC could help mitigate if integrated into institutional procurement policy and practice (Okwuosa, 2025; Radiology procurement assessment, 2014)<sup>[21, 24]</sup>. Enugu State's federal healthcare institutions, like many public hospitals in Nigeria, face constrained budgets, complex supplier markets, and weak biomedical engineering support all factors that make an LCC perspective particularly relevant for guiding sustainable procurement choices.

This study Exploring Life Cycle Costing as a Tool for Sustainable Procurement of Medical Equipment: A Case Study of Selected Federal Healthcare Institutions in Enugu

State” therefore aims to (1) assess current procurement practices and the extent to which life-cycle costs are considered, (2) quantify typical life-cycle cost drivers for selected classes of medical equipment used in the sampled institutions, and (3) identify institutional, technical, and policy barriers and enablers for mainstreaming LCC into procurement decision-making. By linking international LCC principles (ISO 15686-5, IISD guidance) to on-the-ground procurement realities in Enugu, the study aims to produce actionable recommendations to improve equipment availability, lower the total cost of ownership, and strengthen the sustainability of federal health services in the state.

## Literature Review and Theoretical Framework

### Conceptual Review

#### Life Cycle Costing (LCC)

Life Cycle Costing (LCC) is a structured financial evaluation method that assesses the total cost of acquiring, operating, maintaining, and disposing of an asset throughout its entire life span rather than focusing solely on its initial purchase price (ISO, 2017). In public procurement, LCC supports more informed decision-making by quantifying long-term economic implications such as energy use, spare parts, downtime, and end-of-life decommissioning, thereby ensuring value for money and cost-efficient resource utilization (IISD, 2010). For medical equipment, which often incurs high operational and maintenance costs, LCC provides a comprehensive framework for comparing alternatives and forecasting total ownership costs, promoting more sustainable and cost-effective investments (Chang, 2022)<sup>[4]</sup>. Thus, LCC is recognized as a critical tool for improving planning, minimizing unexpected expenditures, and enhancing asset performance across an equipment’s functional life cycle.

#### Sustainable Procurement

Sustainable practices refer to actions and approaches that meet present needs without compromising the ability of future generations to meet their own needs, by balancing environmental protection, social well-being, and economic viability (Ologbonori *et al.*, 2025; Suleiman *et al.*, 2025)<sup>[22, 26]</sup>. They involve conserving natural resources, reducing pollution, minimising waste, promoting fair and equitable social systems, and supporting long-term economic growth through efficient and responsible use of resources (Magaji *et al.*, 2024; Ibrahim *et al.*, 2025; Abuakar *et al.*, 2025)<sup>[10, 16]</sup>. Sustainable procurement refers to the process of integrating economic, environmental, and social considerations into purchasing decisions to ensure that goods and services deliver long-term value while minimizing negative impacts on society and the environment (United Nations Environment Programme [UNEP], 2012; Magaji *et al.*, 2025a)<sup>[17, 18, 29]</sup>. It moves procurement beyond the lowest-price approach by evaluating broader sustainability factors such as energy efficiency, carbon footprint, durability, waste reduction, supplier ethics, and operational cost implications (Brammer & Walker, 2011)<sup>[3]</sup>. In the healthcare sector, sustainable procurement plays a vital role in ensuring that medical products and technologies are safe, reliable, environmentally responsible, and economically feasible across their life cycle (World Health Organisation [WHO], 2017; Ismail *et al.*, 2024)<sup>[14, 31]</sup>. By embedding sustainability criteria, organizations can reduce total costs, enhance public

sector accountability, promote green innovation, and strengthen the long-term resilience of health systems.

#### Medical Equipment

Medical equipment comprises a wide range of devices, tools, systems, and technologies used for diagnosis, treatment, monitoring, rehabilitation, and disease prevention in healthcare settings (WHO, 2011). This category includes simple devices such as thermometers and blood pressure monitors, as well as complex technologies like MRI scanners, ventilators, dialysis machines, and laboratory analyzers. The effective functioning of medical equipment is central to quality healthcare delivery, as equipment failures, downtime, or inadequate maintenance can compromise patient safety and treatment outcomes (Perry & Malkin, 2011; Idoko *et al.*, 2021)<sup>[23]</sup>. Given the high capital and operational costs associated with most medical technologies, their management requires careful planning, appropriate procurement, routine maintenance, user training, and end-of-life disposal strategies. Therefore, ensuring the availability, reliability, and optimal performance of medical equipment is essential for strengthening health service delivery and achieving sustainable healthcare outcomes.

#### Federal Healthcare Institutions

Federal healthcare institutions are government-owned health facilities funded and regulated by the Federal Government to provide specialized, secondary, and tertiary health services to the population (Federal Ministry of Health [FMOH], 2020). These institutions such as Federal Medical Centres, Federal Teaching Hospitals, and specialized national hospitals play crucial roles in delivering advanced medical care, training health professionals, conducting research, and implementing national health policies. As referral hubs, federal healthcare institutions rely extensively on sophisticated medical equipment, biomedical engineering services, and structured procurement systems to ensure effective service delivery (Adebayo & Ugoji, 2018)<sup>[2]</sup>. However, many Nigerian federal health institutions face challenges, including inadequate funding, weak maintenance culture, procurement inefficiencies, and high equipment breakdown rates, which significantly affect operational efficiency and the quality of care (Okwuosa, 2025; Magaji *et al.*, 2025b)<sup>[17, 18, 21]</sup>. Strengthening management systems within these institutions is therefore vital for improving national health system performance and advancing universal health coverage.

#### Theoretical Review

##### Total Cost of Ownership (TCO) Theory

The Total Cost of Ownership (TCO) Theory is highly relevant to the sustainable procurement of medical equipment because it emphasizes that procurement decisions should account for all direct and indirect costs associated with an asset throughout its functional life, rather than focusing solely on its purchase price (Ellram, 1995)<sup>[6]</sup>. According to TCO Theory, hidden costs—such as installation, training, spare parts, consumables, energy use, downtime, maintenance, and disposal often exceed the initial acquisition cost, making life-cycle-based evaluation essential for achieving long-term value for money (Degraeve *et al.*, 2005)<sup>[5]</sup>. In healthcare settings, where medical equipment requires continuous maintenance and reliable performance, TCO provides a strategic framework

that aligns closely with Life Cycle Costing (LCC) by enabling decision-makers to assess the full economic implications of technology choices (Thai, 2009) [27]. Applying TCO Theory in federal healthcare institutions can therefore improve procurement transparency, reduce wastage, enhance cost forecasting, and support sustainability by highlighting the long-term operational and environmental impacts of medical equipment.

### Empirical Review

Khare (2023) [15] examines the Impact of Life Cycle Costing in the Procurement of Robotic Track and Laboratory Equipment. The study employed a comparative life-cycle costing (LCC) methodology using procurement records, service logs, and cost-of-ownership models across two diagnostic laboratories. The study found that lowest-price procurement resulted in high maintenance and downtime costs, while LCC-based procurement identified alternatives that delivered superior value for money across a 10-year equipment lifespan (Khare, 2023) [15]. The author recommended institutionalizing LCC tools in health procurement departments, requiring vendors to submit LCC breakdowns at the bid stage, and training biomedical engineers and procurement officers to interpret long-term cost structures for sustainable procurement.

Seo (2022) [25] investigate How to Calculate the Life Cycle of High-Risk Medical Devices: A Multi-Country Review and Proposal, applied a mixed-methods approach combining literature synthesis with global regulatory analysis from the United States, United Kingdom, Canada, Japan, and South Korea. Findings revealed inconsistencies in defining device lifespan, maintenance intervals, and end-of-life protocols, leading to inaccurate LCC estimations and poor procurement planning (Seo, 2022) [25]. The study recommended harmonizing lifecycle definitions across healthcare institutions, adopting standardized LCC templates for high-risk devices, and integrating lifecycle requirements into tender documents to improve procurement accuracy and sustainability.

Hinrichs-Krapels *et al.* (2022) [9], in their systematic review titled Purchasing High-Cost Medical Devices and Equipment in Hospitals: A Systematic Review of Processes and Methods, reviewed empirical studies using PRISMA guidelines and synthesized evidence from hospitals in high-, middle-, and low-income countries. The review found that hospitals applying structured procurement tools such as LCC, multi-criteria decision analysis (MCDA), and health technology assessments achieved better long-term cost efficiency and reduced equipment downtime compared to facilities using price-only procurement (Hinrichs-Krapels *et al.*, 2022) [9]. The authors recommended embedding LCC models within procurement policy, involving clinical engineers in technical evaluations, and requiring suppliers to disclose service agreements and long-term cost implications during tender processes.

Hillebrecht *et al.* (2022) [8], in the article Contracted-Out Maintenance Provides Cost-Efficient Medical Equipment Maintenance in a Lower-Middle Income Context, conducted a cost-minimization analysis using data from district hospitals in Nepal to compare in-house versus outsourced equipment maintenance. The study found that contracted maintenance significantly reduced operational costs, improved service response times, and increased equipment uptime, especially in resource-constrained health systems

with limited engineering expertise (Hillebrecht *et al.*, 2022) [8]. Incorporate maintenance outsourcing options within LCC evaluations, promote pooled maintenance contracts for small hospitals, and integrate performance indicators such as uptime and service response times in maintenance agreements.

Mang *et al.* (2023) [19], in the study A Medical Equipment Lifecycle Framework to Improve End-of-Life Outcomes and Sustainability, used a mixed-methods design involving stakeholder interviews, field observations, and lifecycle mapping across hospitals and equipment-receiving organizations. The study found that insufficient procurement specifications, weak preventive maintenance systems, and absence of disposal plans increased hidden lifecycle costs and reduced equipment sustainability (Mang *et al.*, 2023) [19]. The authors recommended adopting an end-to-end lifecycle framework in procurement practice, mandating suppliers to provide maintenance and spare-parts guarantees, and institutionalizing equipment asset registers and disposal protocols to enhance sustainability and cost efficiency.

Montesinos (2024) [20], in the article Sustainability Across the Medical Device Lifecycle: Policy and Practice Implications, conducted a qualitative policy analysis supported by case studies and interview data from procurement officers and biomedical engineers in selected hospitals. Findings revealed that institutions integrating sustainability metrics and life-cycle costing into procurement achieved lower long-term expenditure, minimized environmental waste, and improved reliability of medical equipment compared to institutions using price-driven procurement strategies (Montesinos, 2024) [20]. The study recommended embedding environmental sustainability and lifecycle costs into procurement scoring matrices, strengthening procurement staff capacity for LCC analysis, and mandating that suppliers provide comprehensive lifecycle cost details in tender submissions.

### Gap in the Literature

Although existing empirical studies between 2020 and 2025 demonstrate that life cycle costing (LCC) significantly improves long-term value for money, enhances equipment uptime, and strengthens sustainability in healthcare procurement, a notable research gap persists as most of the evidence originates from high-income countries, Asian health systems, or generalized hospital procurement processes, with limited attention to federal healthcare institutions in Nigeria. While studies such as Khare (2023) [15], Seo (2022) [25], and Hinrichs-Krapels *et al.* (2022) [9] highlight the technical and methodological strengths of LCC frameworks, they do not examine how institutional constraints such as weak maintenance culture, budgetary unpredictability, procurement bureaucracy, and limited biomedical engineering capacity—affect LCC adoption in developing contexts. Similarly, findings from Hillebrecht *et al.* (2022) [8] and Mang *et al.* (2023) [19] emphasize the benefits of maintenance planning and lifecycle frameworks but fail to address contextual realities such as supply-chain delays, vendor non-compliance, and inconsistent policy enforcement common in Nigerian federal hospitals. Furthermore, no study provides empirical evidence on the practical implementation, challenges, or effectiveness of LCC in the procurement of medical equipment specifically within Federal Healthcare Institutions in Nigeria, leaving a contextual, methodological, and policy gap that this study seeks to fill.

## Methodology

### Research Design

A mixed-methods research approach will be utilized to address the formulated research questions comprehensively. This approach combines qualitative and quantitative methodologies, allowing for a nuanced understanding of the phenomena under investigation. The qualitative aspect will focus on analyzing the attitudes, behaviors, and experiences of the target population through semi-structured interviews, while the quantitative component will employ descriptive statistics and LCC using NPV to analyze numerical data from secondary sources.

### Population of the Study

The target population for this study comprises two carefully selected federal healthcare institutions in Enugu State, namely, the University of Nigeria Teaching Hospital (UNTH) and the National Orthopaedic Hospital, Enugu (NOHE). These institutions were chosen due to their significance in providing specialized medical services and their involvement in procurement activities related to laboratory healthcare equipment and its complimentary medical consumables.

The study's respondents will include laboratory scientists, biomedical engineers, and procurement officers, as they possess relevant expertise and firsthand experience in healthcare-sector procurement processes. Their insights will be invaluable in understanding the procurement dynamics, challenges, and best practices employed within these institutions.

### Sample and Sampling Techniques

In this study, purposive sampling will be used to select 30 key informants from a total sample of 300 employees across the selected Federal Hospitals, focusing specifically on participants whose expertise aligns with the research objectives. The sample will comprise 25 Procurement Officers, 10 Laboratory Scientists, and 10 Bio-Medical Engineers whose roles and experiences are central to understanding procurement practices, equipment usage, and maintenance considerations. Procurement Officers will provide insights into bid evaluation and the integration of Life Cycle Costing (LCC), Laboratory Scientists will offer perspectives on equipment functionality and operational needs, and Bio-Medical Engineers will contribute knowledge on equipment performance, reliability, and long-term maintenance costs. This targeted selection of knowledgeable professionals ensures the collection of rich, relevant, and informed data, thereby enhancing the reliability and validity of the study while supporting a comprehensive exploration of LCC in sustainable procurement decision-making within federal healthcare institutions.

### Data Collection Methods

Data collection methods are critical for gathering the necessary information to address the research questions effectively. This study will utilize both quantitative and qualitative data collection techniques, ensuring a comprehensive understanding of procurement practices in the healthcare sector.

### Survey

Quantitative data will be obtained through secondary sources, specifically institutional records and procurement

reports. These records provide a wealth of information regarding past procurement practices, including:

- 1. Historical Procurement Spend Data:** This includes information on previous purchases, prices, suppliers, and contract terms. Analyzing this data can reveal trends in procurement decisions and highlight how life cycle costing has been applied in the past.
- 2. Financial Reports:** These documents often contain insights into the financial implications of procurement choices, such as acquisition costs and ongoing operational expenses.

By leveraging existing data, the research can quantitatively evaluate the impact of life cycle costing criteria on procurement processes, providing a robust empirical foundation for the findings.

### Interviews

The study will collect qualitative data through semi-structured interviews, a method that supports focused yet flexible engagement with participants to gain deeper insights into their experiences and perspectives. The interview design will combine predetermined guiding questions with the freedom to explore new themes as they arise, ensuring relevance while allowing participants to share unique viewpoints. During the sessions, the researcher will build rapport to create a comfortable and open environment that encourages honest and detailed discussions about procurement practices and associated challenges. All interviews will be audio-recorded with participants' consent and later transcribed to ensure accuracy and preserve the richness of their responses for analysis. Overall, the interview process is intended to capture nuanced experiences and illuminate how life cycle costing shapes procurement decision-making in practical healthcare settings.

### Focus Groups

Focus groups may also be conducted to explore collective experiences and insights regarding procurement practices. This method involves bringing together a small group of participants who share common characteristics or experiences related to the study. The focus group discussions will provide several advantages:

- 1. Diverse Perspectives:** Participants will have the opportunity to share their views, leading to a richer understanding of the collective experiences and challenges faced in procurement. The group dynamic can stimulate discussions that might not emerge in individual interviews.
- 2. Facilitated Dialogue:** A facilitator will guide the discussion, encouraging interaction among participants while ensuring that key topics are covered. This can lead to the identification of consensus views as well as divergent opinions, providing a multifaceted view of procurement practices.
- 3. Exploration of Themes:** Focus group discussions can help identify common themes and issues that arise in procurement, offering insights into the effectiveness of life cycle costing and its perceived benefits or challenges.

By combining surveys, interviews, and focus groups, the research will gather comprehensive data that reflects both quantitative trends and qualitative insights, facilitating a holistic understanding of procurement practices in the healthcare sector.

**Data Analysis Techniques**

Data analysis techniques will be employed to extract meaningful insights from the collected secondary data, ensuring that the findings address the research questions effectively using LCC Calculations.

**Calculating the Life Cycle Costing**

The study will calculate the total cost of ownership (TCO) of medical equipment using life cycle costing (LCC), comparing it with the initial ownership cost to provide a comprehensive financial assessment. Capital expenditure (Capex) data will be obtained from the Procurement Unit, operational costs from the Medical Laboratory Unit, and maintenance costs, including repairs and servicing, from the Bio-Medical Engineering Unit, along with residual or scrap values. Using five years of historical data from an existing Bio-Chemistry Analyzer model, LCC calculations will consider acquisition, operational, maintenance, and disposal costs, with future cash flows discounted to present value using the formula  $(PV_t = \text{Netflow}_t / (1+r)^t)$ . Outflow per annum will be calculated as the sum of Capex, operating, maintenance, and disposal costs, while inflow per annum will be calculated as the sum of operational output, price, and scrap value. Data analysis will include descriptive statistics to summarize procurement characteristics, frequency tables to visualize cost distributions, and correlation analysis to examine relationships between LCC criteria and procurement decisions. This structured approach aims to provide a holistic understanding of the financial implications of procurement choices and to support informed, sustainable decision-making in federal healthcare institutions.

**Qualitative Data Analysis**

Qualitative data from the semi-structured interviews will be analyzed using thematic analysis, which involves several systematic steps:

1. **Transcription:** All interviews will be transcribed verbatim to ensure that participants' responses are accurately captured for analysis.
2. **Validation:** A review process will be conducted to ensure that the identified themes accurately reflect the data. This involves comparing the themes against the dataset to identify discrepancies and refine the analysis, enhancing the integrity of the findings.

By employing thematic analysis, the research will uncover rich insights into participants' experiences and perceptions of procurement practices and life-cycle costing.

**Ethical Considerations**

Ethics are foundational to conducting research, ensuring that the rights and well-being of participants are prioritized throughout the study.

**Informed Consent**

Participants will be fully informed about the research, including its objectives, procedures, and any potential risks

associated with their participation. This process will involve:

1. **Clear Communication:** Information sheets detailing the study will be provided to participants, explaining their rights and the nature of the research in straightforward language.
2. **Voluntary Participation:** Participants will have the autonomy to choose whether or not to participate, with the assurance that they can withdraw at any time without any consequences.

This emphasis on informed consent fosters trust and empowers participants to make knowledgeable decisions about their involvement in the research.

**Presentation, Analysis, and Interpretation of Data Introduction**

This section presents, analyzes, and interprets the study findings arising from the survey data collected from respondents on exploring life cycle costing as a tool for sustainable procurement of medical equipment in selected Federal Healthcare Institutions in Enugu State. The chapter is organised into five sections; the first introduces the paper, and the second presents the response rate. Thirdly, data presentation and interpretation of the respondents' demographic characteristics; fourthly, data presentation and interpretation of the life cycle costing method in the procurement of medical laboratory equipment; and lastly, the significant findings of the study are discussed.

**Response Rate**

A total of 300 questionnaires were distributed, but 275 were returned, representing a response rate of 91.7%. Table 4.1 summarises the quantitative response rate analysis.

**Table 1:** Response Rate of Questionnaires

Questionnaire	Frequency	Percentage (%)
Administered questionnaires	300	100
Returned questionnaires	275	91.7
Usable Questionnaires	273	91.0
Unusable Questionnaires	02	0.6
Unreturned questionnaires	25	8.3

**Source:** field survey, 2025

Table 1 shows the response rate of the administered questionnaire. 300 copies of the questionnaires were administered, representing 100% of the sampled population; 275 were retrieved, representing a 91.7% response rate, and the remaining 25, with 8.3%, were not retrieved. Accordingly, of the 275 copies of the questionnaire retrieved, 273 were usable, with an adjusted response rate of 91%, and two were unusable because a substantial portion of these copies were incomplete. Therefore, the analysis was based on 273 valid and usable questionnaire copies, yielding a response rate of 91%. This indicates a favourable response rate that permits reasonable deductions and inferences.

**Socio-Demographic Characteristics of Respondents**

Socio-demographic characteristics of the respondents included gender, age, marital status, level of education, religion, profession, and years of service. The results of the analysis are presented in Table 4.2.

**Table 2:** Socio-demographic data of respondents

Gender	Frequency	Percentage (%)
Male	190	69.6
Female	83	30.4
Total	273	100
Age (Year)	Frequency	Percentage (%)
18 – 24	56	20.5
25 - 31	67	24.5
32 - 38	76	27.8
39 and above	74	27.1
Total	273	100
Marital status	Frequency	Percentage (%)
Single	91	33.3
Married	164	60.1
Divorced/Separated	14	5.1
Widow/Widower	4	1.5
Total	273	100
Educational qualification	Frequency	Percentage (%)
NCE/OND/Diploma	112	41.0
HND/First degree	97	35.5
Higher degree	64	23.4
Total	273	100
Religious affiliation	Frequency	Percentage (%)
Islam	76	27.8
Christianity	190	69.6
Traditional religion	7	2.6
Total	273	100
Profession	Frequency	Percentage (%)
Procurement Officer	120	44.0
Laboratory Scientist	64	23.4
Biomedical Engineer	89	32.6
Total	273	100
Years of service	Frequency	Percentage (%)
Less than 5	31	11.4
6 – 10	60	22.0
11 – 15	57	20.9
Above 15	125	45.8
Total	273	100

Source: field survey, 2025

The demographic analysis of respondents indicates a predominance of males, with 190 (69.76%) males compared to 83 (30.4%) females, reflecting the broader gender distribution in formal employment in Nigeria. Age distribution shows a fairly balanced spread: 56 (20.5%) were aged 18–24 years, 67 (24.5%) between 25–31 years, 76 (27.8%) between 32–38 years, and 74 (27.1%) aged 39 years and above. Regarding marital status, the majority of respondents were married (164; 60.1%), followed by singles (91; 33.3%), divorced/separated (14; 5.1%), and widowed/widower (4; 1.5%), suggesting a sample composed mainly of responsible individuals. Educationally, 112 (41%) had NCE/OND/ND qualifications, 97 (35.5%) held first degrees (HND/B.Sc.), and 64 (23.4%) had higher degrees (MSc/PhD), indicating a generally well-educated and knowledgeable sample. In terms of religion, 190 (69.6%) were Christians, 76 (27.8%) Muslims, and 7 (2.6%) adherents of traditional beliefs, representing Nigeria’s dominant religions. Professionally, 120 (44%) were Procurement Officers, 64 (23.4%) Laboratory Scientists, and 89 (32.6%) Biomedical Engineers, providing a diverse perspective across key staff categories. Regarding years of service, 125 (45.8%) had over 15 years of experience, 60 (22%) had 6–10 years, 57 (20.9%) had 11–15 years, and 31 (11.4%) had less than 5 years, indicating that a substantial portion of the respondents had sufficient experience to

provide informed insights on procurement and life cycle costing practices.

**Life cycle costing analysis in the procurement of medical laboratory equipment**

**Objective One:** Awareness, Knowledge and Application of the life cycle costing method in the procurement planning of medical laboratory equipment

This section presents, analyses, and interprets data related to objective one, regarding the awareness, knowledge and application of the life cycle costing method in the in procurement of medical laboratory equipment.

**Table 3:** Response on the awareness of the life cycle costing method

Variable	Frequency	Percentage (%)
Yes	273	100
No	0	0
Total	273	100

Source: Field survey, 2025

Table 3 The Findings from key informant interviews indicate that there is a general awareness and knowledge of life cycle costing (LCC) among procurement professionals, with both novice and experienced staff recognizing its existence and purpose in procurement processes (KII, 2025). Despite this awareness, the study reveals a low rate of actual usage of LCC in the procurement of medical equipment, with 150 (54.9%) of respondents reporting low usage, 98 (35.9%) medium, and only 25 (9.2%) high usage. Key informants corroborated these findings, highlighting persistent challenges and poor implementation practices across institutions. This suggests that although LCC is familiar to staff, its practical application in procurement decisions remains limited, indicating a gap between knowledge and implementation in federal healthcare settings.

**Table 4:** Response on the length of period life cycle costing analysis have been implemented

Response	Frequency	Percentage (%)
Less than 1 year	161	60.0
1 - 5 years	55	20.1
6 - 10 years	41	15.0
Above 10 years	16	5.9
Total	273	100

Source: Field survey, 2025

Table 4 reveals that 161(60%) of the respondents admits that life-cycle costing have been in use for less than 1 years, 55(20.1%) said for the period of 1 - 5 years, 41(15%) stated for the period of 6 – 10 years, while 16(5.9%) said for the period of over 10 years. This implies that, the adoption of life-cycle costing is still at a very early stage, thus, its unpopular approach in the procurement of medical equipment.

**Table 5:** Response on the depth of life cycle costing method implementation in the procurement process

Response	Frequency	Percentage (%)
Planning stage	27	9.9
Implementation stage	25	9.2
Evaluation stage	24	8.8
Throughout the stages	29	10.6
No response	168	61.5
Total	273	100

Source: Field survey, 2025

Table 5 shows that 168(61.5%) of the respondents were neutral in their responses, 29(10.6%) affirmed that life-cycle costing is implemented throughout the procurement stages, 27(9.9%) said implemented at the planning stage, 25(9.2%) implementation stage and 24(8.8%) evaluation stage. Thus, it was clear that life-cycle costing method is not well established and implemented throughout the entire procurement phases of medical equipment.

**Objective Two:** Awareness and application of methods and cost parameters of the life cycle costing analysis in tender process

This section presents, analyses, and interprets data related to objective two, regarding the awareness of existence and usability of methods and cost parameters of the life cycle costing analysis calculation in the procurement of medical laboratory equipment

**Table 6:** Response on the awareness of methods of the life cycle costing analysis

Method	Aware		Not Aware		Total	
	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
Simple pay back	213	78.0	60	22.0	273	100
Discount payback	207	75.8	66	24.2	273	100
Net present	216	79.1	57	20.9	273	100
Equivalent annual cost	218	79.9	55	20.1	273	100
Internal rate of return	254	93.0	19	7.0	273	100
Net saving	199	72.9	74	27.1	273	100

Source: Field survey, 2025

According to Table 6, 254(93%) of the respondents were aware of the availability of Internal Rate of Return (IRR) method of life cycle costing, 218(79.9%) aware of Equivalent annual cost (EAC), 216(79.1%) Net present (NP), 213(78%) Simple Pay Back (SPB), 205(75.8%)

Discount Pay Back (DPB) and 199(72.9%) knew of the existence of Net Saving (NS). Overall, the result indicates that over 79.8% of respondents are aware of all methods of life cycle costing.

**Table 7:** Response on the usability of methods of the life cycle costing

Method	Usability						Total	
	Often		Rarely		Never			
	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
Simple pay back	82	30.0	115	42.1	76	27.8	273	100
Discount payback	76	27.8	82	30.0	115	42.1	273	100
Net present	117	42.9	101	37.0	55	20.1	273	100
Equivalent annual cost	186	68.1	68	24.9	19	7.0	273	100
Internal rate of return	194	71.1	66	24.2	13	4.8	273	100
Net saving	90	33.0	104	38.1	79	28.9	273	100

Source: Field survey, 2025

The results on Table 7 shows that, 115(42.1%) of the respondents rarely use of Simple Pay Back method in life cycle costing calculation, 82(30%) often use while 76(27.8%) never use. Also, 115(42.1%) of the respondents never use Discount Pay Back, 82(30%) rarely use, and 76(27.8%) often use. In addition, 117(42.9%) of the respondents often use Net Present method, 101(37%) rarely use whilst 55(20.1%) never use. More so, 186(68.1%) of the respondents often use Equivalent annual cost method,

68(24.9%) rarely use while 19(7%) never use. Further revealed, 194(71.1%) of the respondents often use Internal Rate of Return method, 66(24.2%) rarely use and 13(4.8%) never use. Finally, 104(38.1%) of the respondents rarely use Net Saving method, 90(33%) often use whilst 79(28.9%) never use. These results show that, internal rate of return and equivalent annual cost methods are usually included in the life cycle costing calculation of data analysis.

**Table 8:** Response on the awareness of cost parameters of the life cycle costing analysis

Cost parameter	Aware		Not Aware		Total	
	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
Initial investment cost	273	100.0	0	0	273	100
Operation cost	273	100.0	0	0	273	100
Maintenance and replacement costs	273	100.0	0	0	273	100
Occupancy costs	261	95.6	12	4.4	273	100
End of investment costs	255	93.4	18	6.6	273	100

Source: Field survey, 2025

From Table 8, all the respondents were aware of the existence of Initial investment cost, Operation costs, and Maintenance and replacement costs parameters of life cycle costing respectively, 95.6% aware of Occupancy costs,

whilst 93.4% knew of the existence of End of investment costs of the parameters of life cycle costing. The overall findings indicate 97.8% of the respondents are aware of all the cost parameters of life cycle costing.

**Table 9:** Response on the usability of cost parameters of the life cycle costing

Cost parameters	Usability						Total	
	Often		Rarely		Never			
	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
Initial investment cost	178	65.2	60	22.0	35	12.8	273	100
Operation cost	199	72.9	52	19.0	22	8.1	273	100
Maintenance and replacement costs	191	70.0	56	20.5	26	9.5	273	100
Occupancy costs	33	12.1	95	34.8	145	53.1	273	100
End of investment costs	31	11.4	83	30.4	159	58.2	273	100

Source: Field survey, 2025

Table 9 above indicates that, 178(65.2%) of the respondents often use of Initial investment cost in life cycle costing calculation, 60(22%) rarely use while 35(12.8%) never use. Similarly, 199(72.9%) of the respondents often use Operation cost, 52(19%) rarely use, and 22(8.1%) never use. Additionally, 191(70%) of the respondents often use Maintenance and replacement cost, 56(20.5%) rarely use whilst 26(9.5%) never use. Equally, 145(53.1%) of the respondents never use Occupancy costs, 95(34.8%) rarely use while 33(12.1%) often use. Lastly, the table illustrated that, 159(58.2%), 83(30.4%) and 31(11.4%) of the respondents never use, rarely use, and often use respectively, End of investment costs in life cycle costing

calculation. Evidently, the parameters that are usually included in the life cycle costing calculation are the operation costs, maintenance and replacement costs, and initial investment cost.

**Objective Three:** Benefits of life cycle costing analysis in the procurement of medical laboratory equipment

This section presents, analyses, and interprets data related to objective three, regarding the benefits of life cycle costing analysis for sustainable procurement of medical laboratory equipment. In this section, the keys used were: Strongly Agree (SA); Agree (A); Undecided (U); Disagree (D); Strongly Disagree (SD)

**Table 10:** Responses on the benefits of life cycle costing analysis in procurement of medical laboratory equipment

Benefit of life cycle costing analysis	SA	A	U	D	SD	Total
Life cycle costing technique integrates risk calculation and assessment methods.	163(59.7%)	88(32.2%)	0(0%)	11(4.0%)	11(4.0%)	273(100%)
Risk assessment augments the accuracy of cost forecasts, accelerating the integration into the examination of unanticipated happenings all through the life cycle costing.	164(60.1%)	103(37.7%)	5(1.8%)	0(0%)	0(0%)	273(100%)
Life cycle costing allows the decision-maker to answer a series of ‘what if’ questions with respect to the various options under consideration.	162(59.3%)	105(38.5%)	5(1.8%)	0(0%)	0(0%)	273(100%)
Life cycle costing is important for minimizing losses and increasing profits	161(59.0%)	102(37.4%)	5(1.8%)	5(1.8%)	0(0%)	273(100%)
Life cycle costing helps to reduce the chance of failure or to maximize opportunities in the projects	160(58.6%)	100(36.6%)	7(2.6%)	6(2.2%)	0(0%)	273(100%)
Life cycle costing assists decision makers in evaluating whole life alternatives so that investment success is maximized	72(26.4%)	67(24.5%)	38(13.9%)	49(17.9%)	49(17.9%)	273(100%)
Life cycle costing makes it possible to identify the scale of the risk, which areas of the project will be affected, what the possible responses could be and the necessary resources required to face the risks.	83(30.4%)	53(19.4%)	27(9.9%)	55(20.1%)	55(20.1%)	273(100%)
Life cycle costing forms a major element in the decision making process during procurement and also in value analysis, especially in today's highly uncertain economic environment	78(28.6%)	59(21.6%)	38(13.9%)	53(19.4%)	45(16.5%)	273(100%)

Source: Field survey, 2025

The data in Table 10, supported by key informant interviews, indicate that life cycle costing (LCC) plays a significant role in integrating risk assessment and enhancing procurement decision-making in medical equipment management. A majority of respondents strongly agreed that LCC improves risk calculation (59.7%), augments the

accuracy of cost forecasts (60.1%), enables decision-makers to evaluate “what if” scenarios (59.3%), minimizes losses and increases profits (59%), and helps reduce project failures or maximize opportunities (58.6%). However, responses were more mixed regarding its role in evaluating whole-life alternatives (26.4% strongly agreed) and in

identifying the scale of risks and necessary responses (30.4% strongly agreed), while a notable proportion disagreed or were undecided. Qualitative insights from interviews reinforced these findings, highlighting LCC as a catalyst for sustainable procurement, risk management, and informed decision-making (KII, 2025). Overall, the results suggest that LCC contributes substantially to sustainable procurement practices by integrating risk assessment, enhancing cost accuracy, supporting scenario analysis, and improving project outcomes, thereby promoting efficiency and quality service delivery in federal healthcare institutions.

**Objective Four:** Challenges faced with life cycle costing analysis implementation in the procurement of medical laboratory equipment

This section presents, analyses, and interprets data related to objective four, regarding the challenges in implementing the life cycle costing analysis in the procurement of medical laboratory equipment

**Table 11:** Responses on whether there is any challenge in the implementation of life cycle costing method

Variable	Frequency	Percentage (%)
Yes	249	91.2
No	7	2.6
No Response	17	6.2
Total	273	100

Source: Field survey, 2025

Table 11 show that majority that 249(91.2%) of the respondents acknowledged that, there is a challenge (s) in the implementation of life cycle costing method while 7(2.6%) of the respondents disagreed with that view; and the remaining 17(6.2%) did not respond to this particular question on the challenges. This implies that, there is an inherent impediment(s) to life cycle costing implementation which affects procurement of medical laboratory equipment directly and indirectly.

**Table 12:** Response on the nature of the Challenge (s) confronting the implementation of life cycle costing method

Variable	Frequency	Percentage (%)
Lack of quality data	66	24.2
Lack of life cycle costing software model	50	18.3
Lack of experience	55	20.1
Insufficient life cycle costing guidelines or framework	60	22.0
Difficulties in understanding life cycle costing’s methodological problems and limitations	42	15.4
Total	273	100

Source: Field survey, 2025

The study findings from Table 12 and key informant interviews indicate that the implementation of life cycle costing (LCC) in medical equipment procurement faces several critical challenges. Quantitative data show that 66 (24.2%) of respondents identified lack of quality data as the main obstacle, followed by 60 (22%) citing insufficient LCC guidelines or frameworks, 55 (20.1%) noting lack of experience, 50 (20.1%) reporting absence of LCC software models, and 42 (15.4%) highlighting difficulties in understanding LCC’s methodological limitations.

Qualitative insights further emphasized that inadequate historical spend data, resource constraints, and structural or management deficiencies hinder effective LCC implementation (KII, 2025). Collectively, these challenges—data unavailability, limited professional expertise, absence of standardized frameworks, and software inadequacies—underscore the significant barriers to fully integrating LCC in procurement practices, limiting its potential to optimize costs, manage risks, and enhance sustainable decision-making in federal healthcare institutions.

**Discussion of Findings**

The findings of this study indicate that while procurement professionals in Nigerian federal healthcare institutions are generally aware of Life Cycle Costing (LCC) and its theoretical applications, its practical usage remains limited. Quantitative and qualitative data reveal that a majority of respondents recognize the importance of LCC in integrating risk assessment, improving cost forecasting, evaluating “what if” scenarios, and minimizing losses, yet only a small proportion actively apply it in procurement decisions. The study highlights several factors contributing to this low adoption, including insufficient quality data, inadequate LCC frameworks and guidelines, lack of professional experience, absence of software tools, and challenges in understanding methodological limitations. These findings suggest a clear gap between knowledge and implementation, underscoring systemic and institutional barriers that hinder the full realization of LCC’s potential in optimizing procurement outcomes.

Furthermore, the study demonstrates that where LCC is applied, it significantly enhances procurement decision-making by promoting more accurate cost evaluations, risk management, and sustainable resource allocation. Key informant interviews emphasized the benefits of LCC in identifying risks, maximizing opportunities, and ensuring long-term financial and operational efficiency. However, the challenges identified particularly the lack of structured data, limited technical expertise, and weak policy enforcement highlight the need for targeted interventions. Overall, the findings underscore the importance of institutionalizing LCC within healthcare procurement through comprehensive policy frameworks, professional capacity building, robust data management, and stakeholder engagement to bridge the gap between awareness and practical implementation, thereby improving sustainability and value for money in medical equipment procurement.

**Conclusions, And Recommendations**

Based on the empirical findings, the study concludes that while procurement professionals in Nigerian federal healthcare institutions possess substantial theoretical awareness of Life Cycle Costing (LCC), there is a pronounced gap between this knowledge and its practical application. This disconnect limits the achievement of strategic procurement objectives, cost efficiency, and sustainability outcomes. The analysis further reveals that LCC holds significant untapped potential to improve long-term financial performance, operational efficiency, and environmental sustainability. However, realizing these benefits requires addressing systemic barriers such as institutional inertia, inadequate technical expertise, limited lifecycle data, and weak policy frameworks.

Institutionalizing LCC within public healthcare procurement is therefore critical for optimizing resource allocation, minimizing lifecycle costs, enhancing asset management, and aligning procurement practices with international sustainability benchmarks.

In response to these conclusions, the study recommends a multi-faceted strategy for effective LCC implementation. Key measures include the development of comprehensive national procurement policies mandating LCC integration, targeted capacity building and professional training for procurement staff and biomedical engineers, and the establishment of robust data collection and management systems. Additional recommendations involve creating standard operating procedures (SOPs) for LCC application, implementing supplier performance and accountability frameworks, securing leadership commitment and institutional advocacy, and promoting stakeholder engagement and public awareness of LCC benefits. Collectively, these interventions provide a practical roadmap to enhance procurement efficiency, financial sustainability, and environmental responsibility, ultimately fostering a resilient, globally aligned healthcare procurement system in Nigeria.

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