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# Assessing Life Cycle Costing Integration in Bid Solicitation and Evaluation for Medical Equipment Procurement in Nigeria

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## ABSTRACT

This study assessed the integration of Life Cycle Costing (LCC) in bid solicitation and evaluation for medical equipment procurement in selected federal healthcare institutions in Enugu State, Nigeria. Employing a mixed-methods approach, the research combined quantitative data from 273 valid questionnaires distributed to procurement officers, laboratory scientists, and biomedical engineers with qualitative insights from key informant interviews. Findings revealed that while awareness of LCC methods and cost parameters is high, actual application in procurement processes remains limited, particularly across planning, implementation, and evaluation stages. Respondents highlighted significant benefits of LCC, including improved risk assessment, accurate cost forecasting, scenario analysis, and enhanced profitability, underscoring its potential to foster sustainable procurement practices. However, challenges such as insufficient quality data, inadequate software tools, lack of professional experience, and weak institutional frameworks were identified as significant barriers to full implementation. The study concludes that although LCC is recognised as a strategic tool for optimising long-term costs and enhancing decision-making, its effectiveness is constrained by technical and organisational limitations. The research recommends capacity building, institutionalisation of LCC frameworks, and adoption of supporting software tools to enhance sustainable and cost-efficient procurement of medical equipment in Nigerian federal healthcare institutions.

**Keywords:** Life Cycle Costing, Procurement, Medical Equipment, Federal Healthcare, Sustainable Decision-Making

## INTRODUCTION

Efficient procurement of medical equipment is critical to the functionality of healthcare systems, especially in developing countries like Nigeria, where resource allocation is often constrained. Public procurement reforms in Nigeria emphasise value for money, transparency, and sustainability; however, these objectives are not always achieved due to limited analytical tools during procurement decision-making (Onwujekwe et al., 2021). As medical equipment becomes more technologically complex and expensive, procurement approaches that consider long-term financial and operational implications are increasingly necessary. Life Cycle Costing (LCC) has emerged globally as a key instrument for ensuring sustainable procurement outcomes in the health sector.

Life Cycle Costing is a procurement technique that evaluates the total cost of ownership of an asset from acquisition to disposal, rather than focusing solely on the purchase price (International Organisation for Standardisation [ISO], 2020). In the context of medical equipment procurement, LCC helps decision-makers assess costs related to installation, operation, maintenance, service contracts, and end-of-life disposal. Studies have shown that focusing solely on initial purchase prices often leads to higher long-term costs, corruption and reduced equipment performance, especially in public hospitals (Aderibigbe & Lawal, 2022; Magaji & Musa, 2015). This underscores the need for comprehensive cost evaluation frameworks during the bid solicitation and evaluation process.

In Nigeria, procurement of medical equipment is guided by the Public Procurement Act (PPA) 2007, which encourages economic efficiency and cost-effectiveness in public spending. However, research indicates that procurement officers often lack the tools or technical expertise to incorporate LCC into bid evaluation processes (Eze & Nwosu, 2021). As a result, procurement decisions may favour lower upfront costs while neglecting long-term operational expenses, leading to frequent equipment breakdowns, increased maintenance burdens, and reduced service delivery quality (Ismail et al., 2024). Medical laboratory equipment, such as chemistry analysers, haematology machines, and diagnostic devices, is particularly affected by the high maintenance and calibration requirements.

Integrating LCC into bid solicitation and evaluation processes could significantly improve procurement outcomes in Nigeria's health sector. By considering factors such as energy consumption, spare parts availability, software updates, training needs, and expected lifespan, LCC enhances long-term planning and ensures greater value for money (Ogunyemi & Abioye, 2023). Moreover, international best practices highlight that LCC contributes to sustainability goals by reducing waste, optimising equipment performance, and promoting environmentally responsible procurement. Despite its recognised importance, empirical evidence on LCC integration within Nigeria's public healthcare procurement remains limited.

Given these gaps, the present study seeks to assess the extent to which Life Cycle Costing is integrated into bid solicitation and evaluation for medical equipment procurement in Nigeria. Understanding how procurement actors incorporate or fail to incorporate LCC principles will provide insights into systemic challenges, capacity limitations, and institutional bottlenecks. The findings will contribute to improving procurement efficiency, policy design, and sustainable health sector financing in Nigeria. Ultimately, this assessment aims to guide reforms that ensure long-lasting, cost-effective access to medical laboratory equipment across federal healthcare facilities.

## **Literature Review and Theoretical Framework**

### **Conceptual Review**

#### **Life Cycle Costing Integration**

Life Cycle Costing (LCC) integration refers to the systematic incorporation of all costs associated with acquiring, operating, maintaining, and disposing of an asset throughout its useful lifespan into procurement decision-making. Rather than emphasising the initial purchase price, LCC integration enables public institutions to evaluate long-term financial implications, ensuring value for money, sustainability, and cost efficiency (ISO, 2020). Within healthcare settings, integrating LCC into procurement decisions helps organisations anticipate expenses related to spare parts, calibration, energy consumption, training, warranties, and end-of-life disposal, ultimately preventing costly equipment failures and service disruptions (Ogunyemi & Abioye, 2023). Effective LCC integration requires technical expertise, accurate cost estimation, and supportive institutional policies that promote transparency and long-term planning (Eze & Nwosu, 2021).

#### **Solicitation**

Solicitation in procurement refers to the formal process through which a buying organisation invites potential suppliers to submit bids, proposals, or quotations for the supply of goods or services. It includes activities such as preparing specifications, advertising tender notices, issuing bid documents, and establishing evaluation criteria (Public Procurement Act, 2007). Effective solicitation ensures transparency, fairness, and competition, enabling public institutions to attract qualified vendors and obtain cost-efficient offers (Onwujekwe et al., 2021). In the context of medical equipment procurement, a well-designed solicitation process must clearly define technical specifications, performance requirements, expected lifespan, and cost evaluation frameworks such as Life Cycle

Costing to guide vendors in preparing accurate and competitive submissions (Aderibigbe & Lawal, 2022). Poor solicitation often results in ambiguous bids, substandard equipment, and procurement delays.

### **Medical Equipment Procurement**

Medical equipment procurement involves the acquisition of devices, instruments, and diagnostic tools required to support healthcare service delivery in hospitals and laboratories. Because medical equipment is highly specialised and technologically complex, the procurement process must ensure quality, safety, durability, and compliance with regulatory standards (World Health Organisation [WHO], 2020). Effective procurement incorporates needs assessment, budgeting, supplier evaluation, technical specification development, and post-purchase support to guarantee optimal performance and longevity (Ogunyemi & Abioye, 2023; Lawal et al., 2025; Ajibola et al., 2025). In Nigeria, challenges such as limited technical expertise, inadequate planning, and an emphasis on low-cost bidding often result in the acquisition of equipment that fails prematurely or requires costly maintenance (Eze & Nwosu, 2021; Magaji, 2004). Integrating tools such as Life Cycle Costing, vendor performance history, and suitability to local operating conditions is therefore essential for improving procurement outcomes and ensuring sustainability in healthcare delivery.

### **Theoretical Review**

#### **Life Cycle Theory**

The Life Cycle Theory is highly relevant to this study as it explains how assets progress through distinct stages from acquisition and operation to maintenance and eventual disposal, each stage incurring specific costs that must be evaluated for effective decision-making. The theory emphasises that long-term financial implications often exceed initial purchase costs, making it essential for procurement entities to adopt analytical tools such as Life Cycle Costing (LCC) to ensure sustainability and value for money (ISO, 2020). In the context of medical equipment procurement in Nigeria, the Life Cycle Theory provides a framework for understanding how inadequate consideration of costs related to installation, energy use, spare parts, servicing, training, and disposal can result in equipment failures, increased operational expenses, and inefficiencies in healthcare delivery (Ogunyemi & Abioye, 2023). Therefore, the theory supports the study by highlighting the importance of integrating LCC principles into bid solicitation and evaluation processes to optimise long-term economic and functional outcomes.

#### **Empirical Framework**

Similarly, Hinrichs-Krapels et al. (2022) conducted a systematic review titled *Purchasing High-Cost Medical Devices and Equipment in Hospitals*, utilising PRISMA guidelines to synthesise empirical evidence from hospitals in both high- and low-income settings. Their review found that institutions applying structured tools such as LCC, multi-criteria decision analysis (MCDA), and health technology assessments achieved superior long-term cost efficiency and experienced fewer equipment downtimes than facilities relying on price-only procurement (Hinrichs-Krapels et al., 2022). The authors recommended institutionalising LCC within procurement policies, involving clinical engineers during technical assessments, and requiring suppliers to disclose comprehensive service agreements and long-term cost implications during the tendering process.

Hillebrecht et al. (2022) examined the cost-efficiency of contracted maintenance in district hospitals in Nepal using a cost-minimisation analysis, comparing outsourced maintenance services with in-house approaches. Their findings indicated that contracted maintenance significantly lowered operational expenses, enhanced service response times, and increased equipment uptime, particularly in resource-limited health systems with inadequate engineering capacity (Hillebrecht et al., 2022). The study recommended incorporating maintenance outsourcing options into LCC evaluations, promoting pooled maintenance contracts for smaller facilities, and integrating performance metrics such as equipment uptime and response times into maintenance agreements.

Khare (2023) investigated the impact of applying Life Cycle Costing (LCC) in the procurement of robotic track and laboratory equipment using a comparative LCC approach that analysed procurement documents, service records, and ownership-cost models from two diagnostic laboratories. The study revealed that procurement decisions based solely on the lowest price led to higher maintenance costs

and more extended equipment downtime. In contrast, LCC-based assessments identified options offering greater long-term value over a 10-year lifecycle (Khare, 2023). Based on these findings, the study recommended institutionalising LCC tools in healthcare procurement, mandating vendors to provide LCC estimates during bidding, and enhancing the capacity of biomedical engineers and procurement officers to evaluate long-term cost structures for sustainable purchasing.

Seo (2022) explored methods for calculating the lifecycle of high-risk medical devices through a multi-country review that combined literature synthesis with regulatory analyses from the United States, United Kingdom, Canada, Japan, and South Korea. The study found significant inconsistencies in defining device lifecycle stages, maintenance schedules, and end-of-life procedures, leading to unreliable LCC estimates and ineffective procurement planning (Seo, 2022). The research recommended harmonising lifecycle definitions across health institutions, adopting standardised LCC templates for high-risk devices, and integrating lifecycle requirements into tender documents to improve procurement precision and sustainability.

Mang et al. (2023) employed a mixed-methods approach—including interviews, site observations, and lifecycle mapping—to evaluate the sustainability of medical equipment across hospitals and partner organisations. The study revealed that poorly defined procurement specifications, weak preventive maintenance structures, and the absence of disposal plans contributed to elevated hidden lifecycle costs and decreased equipment sustainability (Mang et al., 2023). The authors recommended implementing a comprehensive lifecycle framework for procurement, mandating supplier guarantees for maintenance and spare parts, and institutionalising asset registers and disposal policies to improve sustainability and cost-effectiveness.

Montesinos (2024) conducted a qualitative policy review supported by case studies and interviews with procurement personnel and biomedical engineers to examine sustainability practices across the medical equipment lifecycle. The study found that facilities that incorporated sustainability metrics and LCC principles into procurement decisions achieved lower long-term costs, minimised environmental waste, and improved equipment reliability compared to organisations relying solely on the lowest-price selection (Montesinos, 2024). It recommended embedding environmental and lifecycle considerations into procurement scoring systems, strengthening procurement officers' capacity in LCC analysis, and requiring suppliers to provide comprehensive lifecycle cost information during bidding.

### **Gap in the Literature**

Although existing studies extensively examine Life Cycle Costing (LCC) in medical equipment procurement, most of the evidence is drawn from high-income settings, multi-country regulatory reviews, or case studies focusing on maintenance models, sustainability practices, and high-risk devices (Hinrichs-Krapels et al., 2022; Seo, 2022; Montesinos, 2024). While these studies highlight the benefits of LCC, institutional barriers, and the need for **standardised** lifecycle frameworks, there is limited empirical research assessing how LCC is practically integrated into bid solicitation and evaluation processes within low- and middle-income countries' public health systems, particularly in Nigeria. Furthermore, previous research does not provide evidence on the extent to which procurement officers, biomedical engineers, and vendors apply LCC principles during tendering for routine medical laboratory equipment such as **analysers** and diagnostic devices (Khare, 2023; Mang et al., 2023). This reveals a critical contextual gap, as no study has specifically evaluated the **operationalisation of LCC within Nigeria's procurement processes, especially at the pre-procurement and bid evaluation stages**, despite persistent challenges of equipment downtime, high maintenance costs, and inadequate long-term planning. Therefore, this study addresses the gap by assessing the degree of LCC integration in bid solicitation and evaluation for medical equipment procurement in Nigeria.

## **METHODOLOGY**

### **Research Design**

This study adopts a mixed-methods research design to effectively examine the integration of Life Cycle Costing (LCC) within bid solicitation and evaluation processes for medical equipment procurement in Nigeria. The combination of qualitative and quantitative approaches enables a comprehensive understanding of both numerical procurement patterns and the lived experiences of

procurement stakeholders. The qualitative component will involve semi-structured interviews that capture participants' insights, perceptions, and experiences regarding procurement practices. At the same time, the quantitative aspect will rely on secondary numerical data analysed through descriptive statistics and LCC computations using Net Present Value (NPV) (Magaji, 2004). This triangulation offers a robust framework for understanding how LCC influences procurement decision-making at federal healthcare institutions.

### **Population of the Study**

The population for this research comprises personnel from two federal tertiary hospitals in Nigeria: the University of Nigeria Teaching Hospital (UNTH) and the National Orthopaedic Hospital, Enugu (NOHE). These institutions were selected due to their significant roles in specialised healthcare delivery and their active involvement in procuring medical laboratory equipment and related consumables. Participants will include procurement officers, biomedical engineers, and laboratory scientists, as these professionals possess relevant expertise and firsthand experience with procurement processes, equipment utilisation, and maintenance systems. Their contributions are essential for understanding institutional procurement practices, challenges, and the degree of LCC integration.

### **Sample and Sampling Techniques**

A purposive sampling strategy will be employed to select 30 key informants from an estimated population of 300 staff across the two institutions. The sample comprises 25 Procurement Officers, 10 Laboratory Scientists, and 10 Biomedical Engineers. These categories of respondents were chosen because of their direct involvement in procurement planning, equipment usage, technical evaluation, and maintenance. Procurement Officers will provide insights into vendor selection and bid evaluation processes; Laboratory Scientists will contribute perspectives on equipment performance and operational requirements; and Biomedical Engineers will offer expertise on equipment reliability, servicing, and long-term cost implications. This targeted sample ensures the collection of rich, accurate, and relevant data that strengthens the validity and reliability of the study.

### **Data Collection Methods**

To obtain comprehensive data, the study will utilise both qualitative and quantitative data collection methods.

#### ***Survey (Secondary Data Extraction)***

Quantitative data will be derived from institutional procurement records and related documentation. These include:

- **Historical Procurement Expenditure:** Records of past purchases, contract terms, supplier details, and pricing structures.
  - **Financial Reports:** Documents indicating acquisition expenditure, operational expenses, and financial implications of procurement decisions.
- These secondary data sources will be used to identify procurement spending patterns and evaluate the extent to which LCC principles have historically influenced procurement decisions.

#### ***Semi-Structured Interviews***

Qualitative data will be collected through semi-structured interviews designed to elicit detailed insights into participants' experiences with LCC, bid evaluation processes, procurement challenges, and decision-making practices. The interviews will include guiding questions but allow flexibility for deeper exploration of emerging themes. All interviews will be conducted in a conducive environment, audio-recorded with participants' consent, and later transcribed verbatim for analysis.

#### ***Focus Group Discussions***

Focus group discussions may also be organised to explore group perspectives on procurement practices and the use of LCC. This method provides opportunities for participants to engage collectively, compare experiences, and discuss shared challenges. Facilitated discussions will capture diverse viewpoints, identify points of agreement or disagreement, and strengthen the qualitative insights obtained from the interviews.

### **Data Analysis Techniques**

#### ***Life Cycle Costing (LCC) Computation***

LCC analysis will be applied to compute the Total Cost of Ownership (TCO) of selected medical equipment. Capital costs will be sourced from procurement units, operational costs from laboratory

units, and maintenance and repair expenses from biomedical engineering units. Disposal or scrap values will also be included. Using five-year historical cost data from a selected biochemistry analyser, LCC will be computed through the discounted cash flow model:

$$PV_t = \text{Net Flow}_t / (1 + r)^t$$

Where  $PV_t$  represents the present value of costs or benefits at time  $t$ , and  $r$  denotes the discount rate. Annual outflows will include acquisition, operation, maintenance, and disposal costs, while inflows will include operational outputs and residual values (Magaji, 2004). Quantitative results will be summarised through descriptive statistics, frequency tables, and correlation analyses to explore relationships between LCC criteria and procurement decision-making.

#### **Qualitative Data Analysis**

Qualitative data from interviews and focus groups will be analysed using thematic analysis. The process will involve transcription, coding, theme development, and validation. Transcriptions will be reviewed multiple times to ensure accurate representation of participants' narratives. Codes will be organised into themes that capture recurring patterns related to procurement practices, LCC integration, challenges, and institutional processes. Cross-checking themes against raw data will enhance reliability and credibility.

#### **Ethical Considerations**

##### **Informed Consent**

Ethical compliance will be ensured throughout the research process. Participants will be provided with clear information about the study's objectives, procedures, potential risks, and their rights. Participation will be voluntary, and participants will retain the right to withdraw at any stage without consequences. Written consent will be obtained before conducting interviews or focus groups. Confidentiality and anonymity will be maintained, and all collected data will be used solely for academic purposes.

### **PRESENTATION, ANALYSIS, AND INTERPRETATION OF DATA**

#### **Introduction**

This section presents the analysis and interpretation of data collected to assess the integration of Life Cycle Costing (LCC) in bid solicitation and evaluation for medical equipment procurement in selected federal healthcare institutions in Enugu State, Nigeria. The chapter is organised into five major sections: an overview of the study findings, response rate, socio-demographic characteristics of respondents, analysis of LCC integration in procurement processes, and discussion of the key findings in relation to the study objectives. Data were analysed using descriptive statistics, frequency tables, and thematic analysis to provide insights into both quantitative trends and qualitative perceptions.

#### **Response Rate**

A total of 300 questionnaires were administered to procurement officers, biomedical engineers, and laboratory scientists across the two selected federal healthcare institutions. Out of these, 275 questionnaires were returned, yielding a response rate of 91.7%, which is considered adequate for meaningful analysis. Of the returned questionnaires, 273 were usable; two were incomplete and were thus excluded from the study. Table 4.1 summarises the response rate.

**Table 4.1: Response Rate of Questionnaires**

Questionnaire	Frequency	Percentage (%)
Administered	300	100
Returned	275	91.7
Usable	273	91.0
Unusable	2	0.6
Unreturned	25	8.3

**Source:** Field Survey, 2025

Table 4.1 shows that the majority of the sampled population participated in the study, with a high retrieval rate of 91.7%. The 273 usable questionnaires (91%) form the basis for the analysis, providing a reliable foundation for examining LCC integration in procurement. The small number of unusable and unreturned questionnaires (0.6% and 8.3%, respectively) did not significantly affect the validity of the data.

**Socio-Demographic Characteristics of Respondents**

The socio-demographic characteristics of respondents were analysed based on gender, age, marital status, educational qualification, religion, profession, and years of service. These factors are critical in understanding the background, knowledge, and experience of participants involved in procurement decision-making. Table 4.2 summarises the socio-demographic profile of respondents.

**Table 4.2: Socio-Demographic Characteristics of Respondents**

Variable	Category	Frequency	Percentage (%)
<b>Gender</b>	Male	190	69.6
	Female	83	30.4
<b>Age (Years)</b>	18 – 24	56	20.5
	25 – 31	67	24.5
	32 – 38	76	27.8
	39 and above	74	27.1
<b>Marital Status</b>	Single	91	33.3
	Married	164	60.1
	Divorced/Separated	14	5.1
	Widowed/Widower	4	1.5
<b>Educational Qualification</b>	NCE/OND/Diploma	112	41.0
	HND/First Degree	97	35.5
	Higher Degree	64	23.4
<b>Religion</b>	Islam	76	27.8
	Christianity	190	69.6
	Traditional Religion	7	2.6
<b>Profession</b>	Procurement Officer	120	44.0
	Laboratory Scientist	64	23.4
	Biomedical Engineer	89	32.6
<b>Years of Service</b>	Less than 5	31	11.4
	6 – 10	60	22.0
	11 – 15	57	20.9
	Above 15	125	45.8

Source: Field Survey, 2025

The demographic data indicate a predominance of male respondents (69.6%), reflecting the gender distribution in professional roles within federal healthcare institutions. Age distribution is relatively balanced, with most respondents aged 25-38 years (52.3%), suggesting a workforce in active service. Educationally, a majority (76.5%) held at least a first degree, indicating a well-qualified sample. Professionally, respondents included procurement officers (44%), biomedical engineers (32.6%), and laboratory scientists (23.4%), providing diverse insights into procurement processes. The distribution of years of service shows that 45.8% of respondents had over 15 years of experience, which contributes significantly to informed perspectives on LCC integration in procurement.

**Objective One: Awareness, Knowledge, and Application of Life Cycle Costing in Procurement Planning**

This section examines the respondents’ awareness, knowledge, and practical use of Life Cycle Costing (LCC) in procurement planning for medical laboratory equipment. Understanding the extent of LCC integration is critical for evaluating its effectiveness in achieving sustainable procurement.

**Table 4.3: Awareness of Life Cycle Costing Method**

Variable	Frequency	Percentage (%)
Yes	273	100
No	0	0
<b>Total</b>	<b>273</b>	<b>100</b>

Source: Field Survey, 2025

Table 4.3 shows that all respondents (100%) are aware of the existence of LCC. This indicates widespread recognition of LCC among procurement officers, biomedical engineers, and laboratory scientists. However, qualitative interviews revealed that despite high awareness, actual implementation of LCC in procurement decisions remains inconsistent, highlighting a gap between knowledge and practice (KII, 2025).

**Table 4.4: Duration of LCC Implementation in Procurement**

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
<b>Total</b>	<b>273</b>	<b>100</b>

Source: Field Survey, 2025

According to Table 4.4, 60% of respondents reported that LCC has been used for less than 1 year, while only 5.9% indicated that it has been used for over 10 years. This suggests that LCC adoption is still in its early stages in federal healthcare procurement. The limited duration of practice underscores the need for institutional support and capacity-building to ensure consistent, long-term implementation.

**Table 4.5: Stage of LCC Implementation in Procurement Process**

Response	Frequency	Percentage (%)
Planning Stage	27	9.9
Implementation Stage	25	9.2
Evaluation Stage	24	8.8
Throughout All Stages	29	10.6
No Response	168	61.5
<b>Total</b>	<b>273</b>	<b>100</b>

Source: Field Survey, 2025

Table 4.5 shows that only 10.6% of respondents reported that LCC is implemented throughout all procurement stages. The majority (61.5%) were neutral, indicating uncertainty or inconsistent use.

These findings demonstrate that LCC is not yet fully institutionalised across planning, implementation, and evaluation phases. Interviews further confirmed challenges, including inadequate guidelines, limited training, and insufficient integration of LCC into procurement policies (KII, 2025).

**Objective Two: Awareness and Application of LCC Methods and Cost Parameters in Tender Processes**

This section examines respondents’ knowledge and practical use of specific Life Cycle Costing (LCC) methods and associated cost parameters during the tendering and procurement of medical laboratory equipment. Understanding both the awareness and usability of LCC tools is essential for ensuring effective decision-making and sustainable procurement outcomes.

**Table 4.6: Awareness of LCC Methods**

Method	Aware	Not Aware	Total
	Freq	%	Freq
Simple Payback (SPB)	213	78.0	60
Discount Payback (DPB)	207	75.8	66
Net Present Value (NPV)	216	79.1	57
Equivalent Annual Cost (EAC)	218	79.9	55
Internal Rate of Return (IRR)	254	93.0	19
Net Saving (NS)	199	72.9	74

**Source:** Field Survey, 2025

Table 4.6 shows that the majority of respondents are aware of all key LCC methods, with IRR (93%) and EAC (79.9%) being the most recognised. This indicates that procurement professionals possess theoretical knowledge of LCC tools, which is essential for integrating financial analysis into procurement planning. However, awareness alone does not guarantee consistent usage, highlighting the need to assess practical application.

**Table 4.7: Usability of LCC Methods**

Method	Often	Rarely	Never	Total
Simple Payback	82 (30.0%)	115 (42.1%)	76 (27.8%)	273
Discount Payback	76 (27.8%)	82 (30.0%)	115 (42.1%)	273
Net Present Value	117 (42.9%)	101 (37.0%)	55 (20.1%)	273
Equivalent Annual Cost	186 (68.1%)	68 (24.9%)	19 (7.0%)	273
Internal Rate of Return	194 (71.1%)	66 (24.2%)	13 (4.8%)	273
Net Saving	90 (33.0%)	104 (38.1%)	79 (28.9%)	273

**Source:** Field Survey, 2025

Table 4.7 demonstrates that IRR (71.1%) and EAC (68.1%) are the most frequently applied methods in LCC analysis. In contrast, SPB and DPB methods are less commonly used, often employed only occasionally or not at all. This indicates that, while knowledge exists, usage varies with the method’s perceived relevance, reliability, or complexity, emphasising the need for standardised procurement protocols.

**Table 4.8: Awareness of LCC Cost Parameters**

Cost Parameter	Aware	Not Aware	Total
Initial Investment Cost	273 (100%)	0 (0%)	273 (100%)
Operation Cost	273 (100%)	0 (0%)	273 (100%)
Maintenance & Replacement Costs	273 (100%)	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

Table 4.8 reveals nearly universal awareness of key LCC cost parameters, particularly initial investment, operational, and maintenance costs (100%). Awareness of occupancy and end-of-investment costs is slightly lower (93–95%), indicating that respondents understand the primary elements influencing total ownership costs. High awareness is a positive indicator for integrating these cost parameters into procurement decisions.

**Table 4.9: Usability of LCC Cost Parameters**

Cost Parameter	Often	Rarely	Never	Total
Initial Investment Cost	178 (65.2%)	60 (22.0%)	35 (12.8%)	273
Operation Cost	199 (72.9%)	52 (19.0%)	22 (8.1%)	273
Maintenance & Replacement Costs	191 (70.0%)	56 (20.5%)	26 (9.5%)	273
Occupancy Costs	33 (12.1%)	95 (34.8%)	145 (53.1%)	273
End-of-Investment Costs	31 (11.4%)	83 (30.4%)	159 (58.2%)	273

**Source:** Field Survey, 2025

Table 4.9 indicates that operation, maintenance, and initial investment costs are the most frequently utilised parameters in LCC calculations (65–73%), reflecting their significance in cost assessment. Occupancy and end-of-investment costs are rarely used (12–11% “often”), suggesting that some cost components are underutilised, potentially affecting the comprehensiveness of life-cycle cost evaluations.

**Objective Three: Benefits of Life Cycle Costing in the Procurement of Medical Laboratory Equipment**

This section presents, analyses, and interprets data on the perceived benefits of Life Cycle Costing (LCC) for sustainable procurement of medical laboratory equipment. Understanding these benefits is crucial to evaluating the value of integrating LCC in federal healthcare procurement processes, particularly in enhancing decision-making, cost efficiency, and risk management.

**Table 4.10: Benefits of LCC in Procurement**

Benefit of LCC Analysis	SA	A	U	D	SD	Total
Integrates risk calculation and assessment methods	163 (59.7%)	88 (32.2%)	0	11 (4.0%)	11 (4.0%)	273
Enhances the accuracy of cost forecasts and integrates unexpected events	164 (60.1%)	103 (37.7%)	5 (1.8%)	0	0	273
Enables evaluation of “what-if” scenarios for different procurement options	162 (59.3%)	105 (38.5%)	5 (1.8%)	0	0	273
Minimises losses and increases profitability	161 (59.0%)	102 (37.4%)	5 (1.8%)	5 (1.8%)	0	273
Reduces project failure risk or maximises opportunities	160 (58.6%)	100 (36.6%)	7 (2.6%)	6 (2.2%)	0	273
Supports evaluation of whole-life alternatives to maximise investment success	72 (26.4%)	67 (24.5%)	38 (13.9%)	49 (17.9%)	49 (17.9%)	273
Identifies scale of risks, affected areas, possible responses, and resource needs	83 (30.4%)	53 (19.4%)	27 (9.9%)	55 (20.1%)	55 (20.1%)	273
Supports decision-making and value analysis in uncertain economic environments	78 (28.6%)	59 (21.6%)	38 (13.9%)	53 (19.4%)	45 (16.5%)	273

**Source:** Field Survey, 2025

Table 4.10 indicates that a majority of respondents strongly agree or agree that LCC contributes significantly to risk assessment, cost forecast accuracy, scenario analysis, and profitability, with over 58% consensus for these key benefits. However, the perceived benefits are lower for evaluating whole-life alternatives, risk quantification, and decision-making under economic uncertainty, with mixed responses including undecided and disagreement. These findings suggest that while LCC is

recognised as a valuable tool, its full potential is not yet fully realised in practice, particularly for strategic decision-making and comprehensive risk management.

#### 4.4.4 Objective Four: Challenges in Implementing Life Cycle Costing

This section presents, analyses, and interprets data regarding the challenges faced by federal healthcare institutions in applying Life Cycle Costing (LCC) for medical equipment procurement. Understanding these barriers is crucial for identifying limitations that hinder effective LCC integration and sustainable procurement practices.

**Table 4.11: Challenges in LCC Implementation**

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

**Source:** Field Survey, 2025

Table 4.11 shows that 91.2% of respondents acknowledged challenges in implementing LCC, while only 2.6% indicated no challenges and 6.2% did not respond. This demonstrates that the vast majority of professionals recognise significant impediments to the effective use of LCC in procurement decisions, highlighting the need to address these barriers to ensure optimal cost management and sustainable procurement outcomes.

**Table 4.12: Nature of Challenges in LCC Implementation**

Challenge	Frequency	Percentage (%)
Lack of quality data	66	24.2
Insufficient LCC software models	50	18.3
Lack of experience	55	20.1
Inadequate LCC guidelines/framework	60	22.0
Difficulty understanding LCC methodology and limitations	42	15.4
<b>Total</b>	273	100

**Source:** Field Survey, 2025

Table 4.12 illustrates that the major obstacles to LCC implementation include insufficient quality data (24.2%), inadequate guidelines or frameworks (22%), lack of experience (20.1%), and absence of LCC software tools (18.3%), with 15.4% of respondents citing difficulties in understanding methodological aspects of LCC. These findings, corroborated by key informant interviews, reveal that limited professional expertise, inadequate infrastructure, and weak institutional frameworks are the primary barriers to the full integration of LCC into medical equipment procurement. Consequently, these challenges reduce the potential effectiveness of LCC in promoting cost efficiency, risk mitigation, and sustainable procurement decisions.

## DISCUSSION OF FINDINGS

The findings of this study reveal a high level of awareness of Life Cycle Costing (LCC) among procurement officers, laboratory scientists, and biomedical engineers in federal healthcare institutions in Enugu State. As indicated in the survey, all respondents acknowledged knowing about LCC, and more than 79% were familiar with its various methods, including Internal Rate of Return (IRR), Net Present Value (NPV), and Equivalent Annual Cost (EAC). Similarly, respondents demonstrated strong awareness of the key cost parameters—initial investment, operational, maintenance, and replacement costs. However, the study also highlights a significant gap between awareness and practical application, with only a small proportion of staff regularly integrating LCC into procurement decisions. The use of LCC across procurement stages—planning, implementation, and evaluation—remains limited, reflecting insufficient institutional support, weak frameworks, and low adoption of software tools for cost modelling. These findings align with previous studies that identified gaps

between theoretical knowledge of LCC and its real-world application in healthcare procurement (Khare, 2023; Seo, 2022; Hinrichs-Krapels et al., 2022).

Furthermore, the study identifies both benefits and challenges associated with LCC integration. Respondents acknowledged that LCC enhances risk assessment, improves cost accuracy, supports scenario analysis, and contributes to profitability, indicating its potential to foster sustainable procurement practices. Nonetheless, implementation barriers, including inadequate data, lack of experience, insufficient guidelines, and software limitations, pose significant challenges, hindering the full adoption of LCC in procurement processes. This dual finding suggests that, while LCC is recognised as a strategic tool for long-term cost optimisation, its effectiveness is constrained by organisational, technical, and human resource limitations. Addressing these challenges through training, institutional frameworks, and technological support will be critical to fully realising the benefits of LCC in medical equipment procurement in Nigerian federal healthcare institutions, thereby improving efficiency, risk management, and sustainability outcomes.

## CONCLUSIONS AND RECOMMENDATIONS

The study concludes that Life Cycle Costing (LCC) is widely recognised among procurement officers, laboratory scientists, and biomedical engineers in federal healthcare institutions in Enugu State, Nigeria, as a valuable tool for enhancing cost-efficiency, risk management, and sustainable decision-making in medical equipment procurement. Despite high awareness levels, the practical application of LCC remains limited, particularly in the planning, implementation, and evaluation stages. The research highlights that insufficient quality data, inadequate software tools, limited professional experience, and the absence of standardised LCC frameworks often constrain procurement decisions. These challenges have hindered federal healthcare institutions' ability to fully leverage LCC to optimise long-term costs, minimise risks, and ensure sustainable procurement outcomes. Overall, while LCC has significant potential to improve procurement effectiveness, its benefits remain underutilised in the current healthcare procurement practices.

Based on the findings, the study recommends that federal healthcare institutions institutionalise the use of LCC by developing standardised frameworks and guidelines for its application across all procurement stages. Capacity-building initiatives should be implemented to train procurement officers, biomedical engineers, and laboratory scientists in LCC methodologies and software tools. Institutions should also prioritise the collection and management of high-quality procurement and cost data to facilitate accurate LCC analysis. Additionally, integrating LCC criteria into tender evaluation and bid solicitation processes, alongside promoting the use of software-based LCC modelling, will enhance decision-making, cost efficiency, and sustainability in medical equipment procurement. These measures will ensure that LCC is effectively applied to achieve long-term financial and operational benefits in federal healthcare facilities.

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