



ASSESSING HOSPITAL AIR-CONDITIONING SYSTEM MANAGEMENT AT THE NATIONAL HOSPITAL, ABUJA IN RELATION TO TOTAL QUALITY MANAGEMENT PRINCIPLES

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Received: 20-12-2025

Revised: 14-01-2026

Accepted: 18-01-2026

Published: 13-01-2026

Abstract: *Effective management of hospital air-conditioning systems is critical to patient comfort, staff productivity, as well as infection control in healthcare facilities. This study assessed air-conditioning management practices at h Total Quality Management (TQM) principles. A quantitative survey design was adopted, and data were collected from clinical staff, patients on admission, and maintenance personnel. A total of 284 valid responses were obtained, representing a response rate of 90.7%. Descriptive statistics and chi-square tests were employed for data analysis using IBM SPSS. The findings reveal substantial deficiencies in system reliability, maintenance responsiveness, and preventive servicing. Only 12.5% of respondents strongly agreed that air-conditioning units are consistently functional, while over 50% expressed dissatisfaction with temperature regulation and indoor air quality. Maintenance inefficiencies were evident, as 43.7% of respondents disagreed that faults were addressed promptly. Chi-square analysis indicated a statistically significant disparity between existing management practices and TQM-aligned benchmarks ($p < 0.05$), suggesting weak adherence to key TQM principles such as preventive maintenance, continuous improvement, and data-driven decision-making. Furthermore, 89.9% of respondents supported the adoption of IoT-based real-time monitoring systems as a proposed improvement strategy. The study concludes that current air-conditioning management practices exhibit limited conformity with TQM principles and highlights the need for structured, quality-driven, and technology-supported maintenance frameworks to improve system reliability and service delivery in public healthcare facilities.*

Key words: Air-conditioning management, Total Quality Management, healthcare facilities, maintenance efficiency, preventive maintenance

1 Introduction

The management of hospital air-conditioning systems is a critical yet often overlooked component of healthcare facility operations. Effective heating, ventilation, and air conditioning (HVAC) systems are vital for maintaining indoor air quality, patient comfort, and infection control within hospitals (ASHRAE, 2022; Saran *et al.*, 2020). According to ASHRAE healthcare HVAC guidelines, continuous monitoring, timely maintenance, and adherence to operational standards are essential for ensuring thermal comfort, air quality, and infection control in

hospital environments (ASHRAE, 2022). Inadequate management of these systems can lead to increased operational costs, frequent equipment breakdowns, and compromised patient care environments, particularly in critical care units (Saran *et al.*, 2020; Alassafi *et al.*, 2024). Despite the importance of HVAC systems, many hospitals face challenges related to inefficient maintenance and suboptimal monitoring procedures. Industry reports have similarly highlighted the operational and energy-related consequences of inadequate HVAC management in healthcare facilities (Cooling India, 2025). Preventive maintenance has been identified as

a critical factor in sustaining HVAC system reliability and reducing life-cycle costs in hospital environments, yet remains inadequately implemented in many public healthcare facilities (Shohet & Lavy, 2019). The transition from reactive to predictive maintenance supported by digital monitoring tools is consistent with established maintenance engineering principles that emphasize data-driven decision-making and continuous improvement (Mobley, 2020).

Total Quality Management (TQM) principles have been widely adopted in healthcare settings globally to enhance service delivery, operational efficiency, and patient satisfaction (Abu-Daqr & Constantinovits, 2020; Akhorshaideh *et al.*, 2023; Babatunde *et al.*, 2015; Vincent *et al.* 2019; Sadikoglu and Olcay's 2014; Ibrahim, 2013). These principles emphasize continuous improvement, stakeholder involvement, process optimization, and data-driven decision-making (Brinia & Malakelli, 2017). Previous studies have demonstrated the positive impact of TQM on hospital management processes, including clinical and administrative functions (Jrad, 2024; El-Tohamy & Al Raoush, 2015). However, the application of TQM specifically to the management of hospital HVAC systems remains under-explored, especially in the context of public healthcare institutions in Nigeria.

This study aims to bridge this gap by examining the effectiveness of Total Quality Management principles in managing the air-conditioning systems at the National Hospital, Abuja. Specifically, it evaluates the existing management approaches, focusing on maintenance and monitoring practices, and analyzes how these current methods influence the performance and reliability of the hospital's air-conditioning units. By comparing these practices with established TQM principles, this paper seeks to identify areas for improvement that can lead to enhanced system reliability, cost efficiency, and overall hospital effectiveness.

Understanding the interplay between TQM and HVAC management within healthcare facilities is essential for promoting sustainable infrastructure maintenance and ensuring the delivery of quality patient care (Hu *et al.*, 2024). Recent studies have demonstrated that IoT-enabled HVAC monitoring systems can significantly improve fault detection, energy efficiency, and maintenance responsiveness in large building facilities (Kim *et al.*, 2021; Shaikh *et al.*, 2020). The findings of this study have the potential to inform policymakers and hospital administrators in Nigeria and similar contexts on best practices for

HVAC system management, ultimately contributing to safer and more efficient healthcare environments.

2 Methodology

2.1 Hypotheses

This study is guided by two null hypotheses formulated based on the research questions:

H₀₁: Existing air-conditioning management practices at the National Hospital, Abuja do not significantly align with key Total Quality Management principles.

H₀₂: Stakeholders do not perceive that adopting TQM-aligned and IoT-supported management approaches would significantly improve air-conditioning system performance.

2.2 Research Design

A quantitative research design was adopted to empirically assess the effectiveness of TQM principles in the management of hospital air-conditioning systems. Quantitative methods provide empirical rigour and enable actionable insights through statistical analysis of structured data (Lim *et al.*, 2024). The primary data collection instrument was a structured questionnaire, which was administered to three distinct stakeholder groups at the National Hospital: admitted patients, clinical staff (including medical doctors and nurses), and maintenance technicians/engineers responsible for air-conditioning system upkeep.

2.3 Sample Size and Sampling Technique

The total population for the study was 1,450 individuals, encompassing patients, clinical staff, and maintenance personnel. Using a confidence level of 95% and a precision level of 5%, the sample size was calculated via the standard formula (Equation 1):

$$n = \frac{N}{1 + Ne^2} \tag{1}$$

Where 'N' is the population size (1,450) and 'e' is the level of precision (0.05).

Stratified sampling was employed to ensure proportional representation across the three groups, as per the stratified sampling formula (Equation 2):

$$ni = \frac{Ni}{N} \times n \tag{2}$$

Where *ni* is the sample size for group ‘i’, *Ni* is the population size of group ‘I’, *N* is the total population size, and ‘n’ is the total sample size.

Using eligibility and response rates tailored to the population characteristics (eligibility rate = 0.75; response rate = 0.5), the calculated patient sample size was 61. For clinical staff (population 1,033) and maintenance staff (population 134), sample sizes were 223 and 29 respectively. The total sample size was 313 respondents, who were selected and surveyed over a period of 50 days.

2.4 Data Collection

Quantitative data were collected through three variations of a structured questionnaire, each tailored to one of the stakeholder groups:

Clinical staff and maintenance personnel: The questionnaires contained three sections which were personal biodata, questions addressing research objectives related to maintenance and monitoring practices, and items related to knowledge and application of Internet of Things (IoT) technologies.

Patients: The questionnaire had two sections namely personal information and experiential ratings of hospital services, specifically focusing on air-conditioning system performance.

The questionnaires targeted key performance measures including equipment availability, service quality, maintenance responsiveness, funding adequacy, adherence to manufacturers’ guidelines, and overall user satisfaction. Respondents evaluated these measures relative to TQM principles such as leadership, customer focus, knowledge, involvement, continual improvement, and conducive working conditions.

A 5-point Likert scale was used to capture respondents’ attitudes and perceptions, where 1 = Strongly Disagree and 5 = Strongly Agree. This scale was chosen for its ease of understanding, reliability, and ability to quantify subjective measures.

2.5 Data Presentation and Analysis

Collected data were analyzed using IBM SPSS Statistics. Reliability of the questionnaire constructs was assessed using Cronbach’s alpha. Descriptive statistics, including frequencies and percentages, were used to summarize respondent perceptions. Chi-

square tests of association were employed to examine differences between observed management practices and TQM-aligned benchmarks, as well as stakeholders’ perceptions regarding the adoption of IoT-based monitoring systems. Statistical significance was assessed at the 5% level ($p < 0.05$).

Descriptive statistics and chi-square tests were used to evaluate differences between observed management practices and TQM-aligned benchmarks. Statistical significance was assessed at the 5% level ($p < 0.05$).

This study assessed stakeholders’ perceptions of current air-conditioning management practices and the perceived feasibility of IoT-based monitoring systems. No experimental deployment or physical installation of IoT devices was conducted

3 Result and Discussion

3.1 Response Rate and Respondent Profile

A total of 284 valid questionnaires were returned from the 313 distributed, representing a 90.7% response rate, which is considered excellent for survey-based studies and indicative of reliable data quality. The respondents comprised clinical staff (73.2%, $n = 208$), patients on admission (16.9%, $n = 48$), and maintenance personnel (9.8%, $n = 28$), ensuring balanced representation of key stakeholders involved in air-conditioning system usage and management at the National Hospital, Abuja. The distribution of respondents is presented in Figure 1.

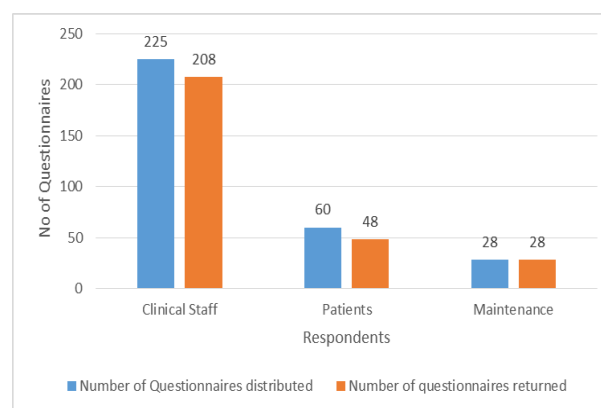


Figure 1: Distribution of survey respondents across stakeholder groups at the National Hospital, Abuja.

3.2 Existing Air-Conditioning Management Practices

Stakeholder assessments revealed widespread dissatisfaction with the performance and reliability of the hospital’s air-conditioning systems. Only 12.5% of respondents strongly agreed that air-conditioning units were consistently functional, while more than half expressed dissatisfaction with temperature regulation and indoor air quality. Frequent system failures were commonly reported, indicating unstable operational performance and inadequate system reliability.

Maintenance and monitoring efficiency were also rated poorly. As presented in Figure 2, 43.7% of respondents disagreed that faults were addressed promptly, and 58.3% reported prolonged fault resolution times. In addition, communication regarding repair progress was inadequate, with many respondents indicating that they were rarely informed about maintenance status. These findings reflect a predominantly reactive maintenance culture, which is inconsistent with preventive maintenance practices emphasized under Total Quality Management (TQM).

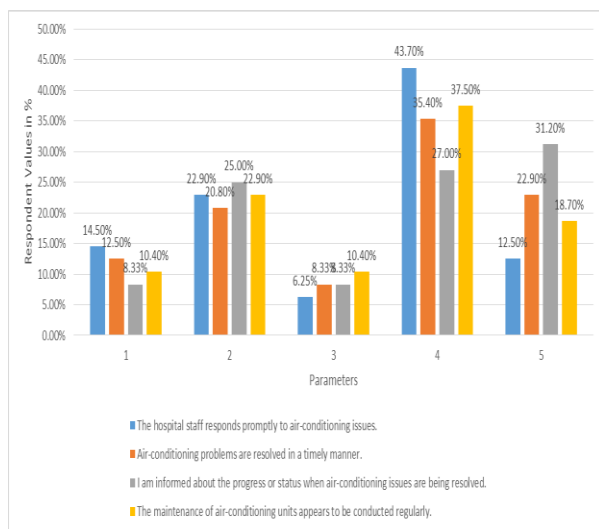


Figure 2: Evaluation of maintenance responsiveness and monitoring efficiency of air-conditioning systems.

3.3 Impact of Current Practices and Comparison with TQM

The operational implications of poor air-conditioning management were significant. As illustrated in Figure 4, approximately 90% of respondents agreed that air-conditioning performance directly affects staff

productivity and patient care. However, 72.1% disagreed that the existing system is reliable, and 67.7% indicated that repairs are neither timely nor effective.

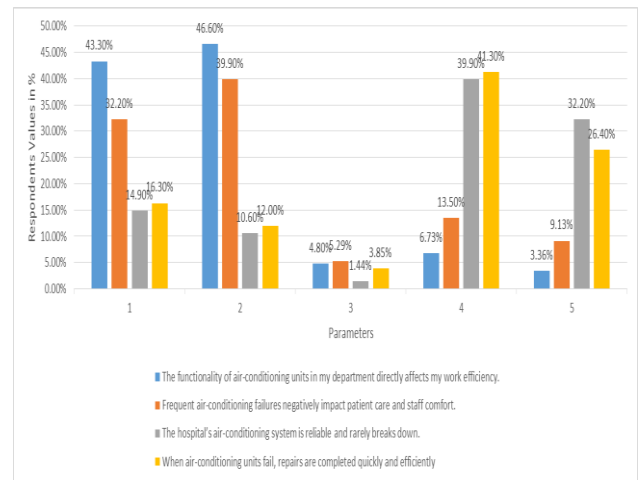


Figure 3: Impact of air-conditioning system performance on staff efficiency and patient care.

productivity and patient care. However, 72.1% disagreed that the existing system is reliable, and 67.7% indicated that repairs are neither timely nor effective. Further comparison with TQM principles further highlights structural weaknesses. Figure 4 demonstrates that routine preventive maintenance, continuous monitoring, and staff training core elements of TQM are inadequately implemented. While 76.2% of respondents acknowledged the presence of feedback mechanisms for reporting faults, only 24% believed that regular training and continuous improvement strategies were prioritized. This partial alignment suggests that although communication channels exist, they are not supported by systematic quality improvement processes.

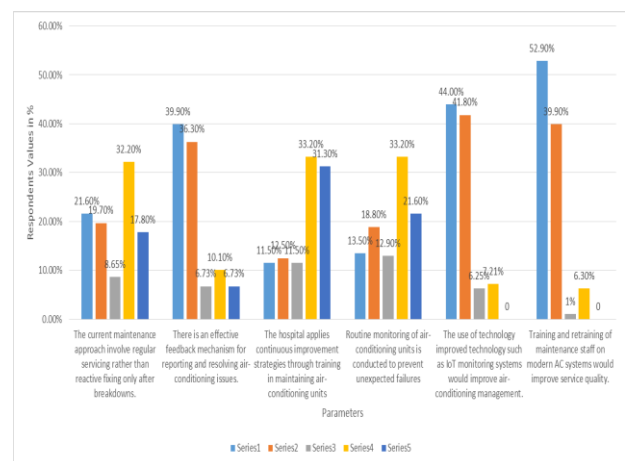


Figure 4: Comparison of existing air-conditioning management practices with Total Quality Management principles

3.4 Feasibility of IoT-Based Air-Conditioning Management

Despite dissatisfaction with current practices, stakeholders showed strong support for technology-driven improvements. As illustrated in Figure 5, 89.9% of respondents supported the adoption of IoT-based real-time monitoring, 96.1% endorsed automated maintenance request systems, and 87.4% recommended investment in newer, energy-efficient air-conditioning units. These findings reflect readiness for proactive, data-driven maintenance approaches consistent with TQM philosophy.

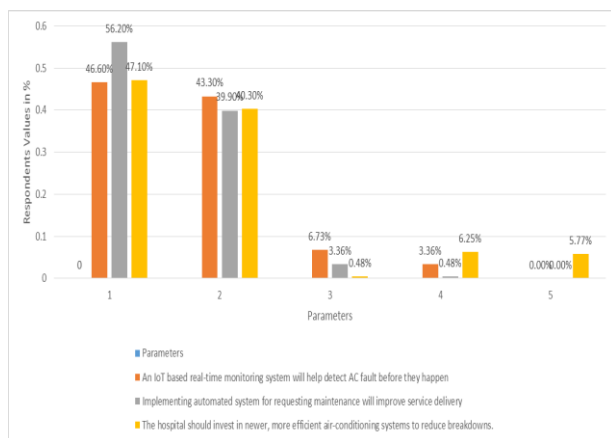


Figure 5: Stakeholders' support for TQM-aligned and IoT-based improvement strategies.

However, implementation feasibility remains constrained by institutional challenges. Based on responses from maintenance personnel (n = 28), Figure 6 indicates that high implementation cost, need for extensive staff training, system complexity, and data security concerns are perceived as major barriers. Only 14.3% of respondents believed that existing infrastructure is adequate to support IoT deployment, underscoring the need for phased implementation supported by investment and capacity building. The strong stakeholder support for IoT-based monitoring observed in this study aligns with prior findings that highlight the effectiveness of real-time HVAC performance monitoring and predictive maintenance using IoT technologies (Kim et al., 2021; Shaikh et al., 2020).

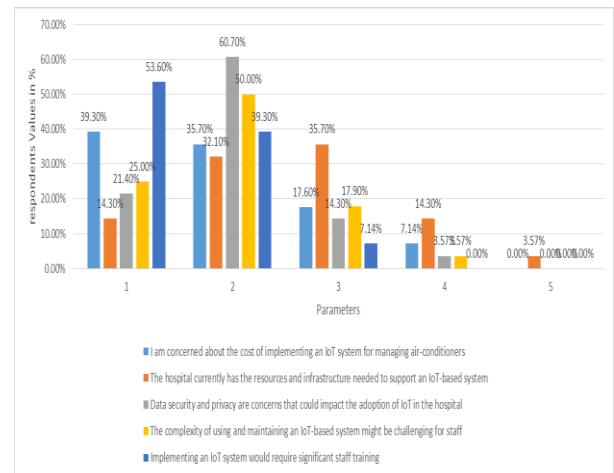


Figure 6: Perceived challenges to IoT-based air-conditioning management implementation (maintenance staff, n = 28).

3.5 Discussion and Implications

Overall, the findings demonstrate that air-conditioning management at the National Hospital, Abuja exhibits weak alignment with Total Quality Management principles, particularly in preventive maintenance, continuous improvement, and performance monitoring. The predominance of reactive maintenance practices contributes to frequent system failures, reduced comfort, and compromised operational efficiency.

Nevertheless, the strong stakeholder support for IoT-enabled monitoring and automation presents a viable pathway for reform. Integrating IoT technologies within a TQM framework could enable real-time performance tracking, predictive maintenance, reduced downtime, and improved energy efficiency. For successful implementation, hospital management must address infrastructural gaps, invest in staff training, and establish governance structures that align technological innovation with quality management objectives.

4 Conclusion

This study demonstrates that air-conditioning system management at the National Hospital, Abuja is predominantly reactive and exhibits weak alignment with Total Quality Management principles. Deficiencies in preventive maintenance, monitoring, and staff capacity contribute to frequent system failures and reduced operational efficiency. Nevertheless, strong stakeholder support for IoT-enabled monitoring indicates readiness for data-driven maintenance transformation. Integrating IoT technologies within a structured TQM framework

offers a viable pathway for improving HVAC system reliability, energy efficiency, and service delivery in public healthcare facilities.

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