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ASSESSMENT AND IMPROVEMENT OF VENTILATION AND AIR CONDITIONING (HVAC) SYSTEMS FOR ENHANCED INDOOR COMFORT IN SELECTED BUILDINGS IN BENIN CITY, NIGERIA

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Abstract

Efficient ventilation and air conditioning (VAC) systems are crucial for maintaining indoor air quality and thermal comfort. This study evaluates the performance and optimization of the VAC system at Crown Height Pavilion Event Center, Benin City. Key parameters such as airflow rate, cooling load, temperature variation, humidity levels, power consumption, energy efficiency, and the coefficient of performance (COP) were analyzed to determine system efficiency. Field measurements revealed an airflow rate of 119.1 CMM, below the ASHRAE-recommended 127.35 CMM, indicating inadequate ventilation. The required cooling load was 31 tons (109.03 kW), while the installed system provided only 24 tons, leading to a 7-ton shortfall (22.5%). This resulted in high indoor temperatures (27 – 32°C) and humidity levels (60%–75%), exceeding recommended ranges. The system's COP was calculated as 3.64, signifying moderate efficiency, though operational inefficiencies increased energy consumption.

Keywords: *Humidity levels, Ventilation, Energy efficiency, Airflow rate, Cooling load, Temperature variation, Power consumption and Coefficient of Performance (COP).*

1.0 INTRODUCTION

The demand for air conditioning systems has risen significantly due to increasing global temperatures, rapid urbanization, and the growing need for indoor comfort. Rising global temperatures have led to increased heat stress in buildings, making air conditioning systems a necessity rather than a luxury. In developing nations such as Nigeria, climate change, population growth, and expanding commercial activities have amplified the demand for cooling solutions (ASHRAE, 2017).Benin City, like many urban centers in Nigeria, experiences high temperatures and humidity levels, particularly during the dry season. These climatic conditions necessitate efficient Heating, Ventilation and Air Conditioning (HVAC) systems to provide thermal comfort, ensure indoor air quality, and maintain energy efficiency. However, many buildings in Benin City, including residential, commercial, and public spaces, suffer from suboptimal Heating, Ventilation and Air Conditioning (HVAC) performance due to poor system design, inadequate capacity, and inefficient energy use (Ebohon and Rwelamila, 2016). The performance of HVAC systems is heavily influenced by various factors such as building insulation, ventilation design, cooling load requirements, and power supply consistency (Oluwaseun and Adewale, 2021). In Nigeria, the inconsistent electricity supply poses a major challenge, forcing many buildings to rely on alternative power sources such as diesel generators, which significantly increase operational costs. Additionally, outdated HVAC systems and lack of routine maintenance contribute to reduced system efficiency and occupant discomfort (Emodi, and Boo, 2015). A well-functioning HVAC system plays a crucial role in improving productivity and well-being in indoor environments. Studies have shown that poor indoor air quality can lead to health issues such as respiratory problems, fatigue, and reduced cognitive function. Proper ventilation, cooling efficiency, and humidity control are essential for creating a healthy indoor atmosphere (Cengel, and Boles, 2015). Therefore, optimizing HVAC systems in Benin City is imperative for enhancing indoor comfort while promoting energy efficiency and sustainability.

This study investigates the performance of the Ventilation and Air Conditioning (VAC)system at Crown Height Pavilion Event Center in Benin City. The research assesses the effectiveness of airflow distribution, cooling load adequacy, and energy consumption. The findings will inform strategies for improving HVAC performance through enhanced design, smart control technologies, and sustainable energy solutions.

2.0 METHODOLOGY

This study was conducted at Crown Height Pavilion Event Center at Ugbowo in Benin City, which experiences high occupancy and cooling demands. The methodology was designed to assess HVAC performance comprehensively through multiple analytical approaches. The research was carried out in the following phases:

2.1 Site Selection and Setup

Crown Height Pavilion Event Center was chosen due to its high occupancy levels and significant cooling demands. A preliminary survey was conducted to assess existing HVAC installations and system configurations.

2.2 Instrumentation and Data Collection

Various high-precision instruments were used to collect real-time data, including:

1. Temperature/Relative Humidity Data Loggers: to record indoor temperature and humidity.
2. Anemometers to measure airflow rate and air velocity.
3. Power Meters to monitor energy consumption by HVAC units.
4. Infrared Thermometers to assess heat gain and insulation effectiveness.

The parameters used in this study were obtained through direct field measurements and analytical calculations. These parameters include:

1. Airflow Rate: Measured using an anemometer at various air vents to assess ventilation efficiency.
2. Cooling Load: Computed based on standards using heat transfer calculations that factor in insulation, occupancy, and external heat gains.
3. Temperature Range: Recorded over time using HOBO Temperature Data Loggers to capture daily fluctuations.
4. Humidity Levels: Measured with relative humidity sensors placed at different zones of the event center.
5. Coefficient of Performance (COP): Derived from the formula, with data from power meters and cooling output calculations.
6. Power Consumption: Monitored using digital power meters to track HVAC energy usage over different operating conditions.

2.3 Cooling Load Calculation

The building's cooling requirements were estimated using the ASHRAE cooling load equation:

$$Q = U \times A \times \Delta T \quad (1)$$

where:

Q = Cooling load (kW)

U = Heat transfer coefficient of materials (W/m^2K)

A = Surface area exposed to heat gain (m^2)

ΔT = Temperature difference between indoor and outdoor environments (°C)

2.4 Energy Performance Analysis

The system's energy efficiency was analyzed by calculating the Coefficient of Performance (COP):

$$COP = \frac{Cooling\ Output\ (kW)}{Power\ Input\ (kW)} \quad (2)$$

3.0 RESULTS AND DISCUSSION

These results and findings are shown on Table 1, Figure 1 and 2 respectively. The temperature variation graph illustrates fluctuations in temperature over time within the event center. It shows a gradual increase from 27°C in the morning to a peak of 32°C in the early afternoon before declining slightly. This pattern indicates the HVAC system struggles to maintain a stable indoor climate, leading to discomfort for occupants. The findings emphasize the need for additional cooling capacity and better insulation to manage thermal loads effectively.

The energy efficiency graph highlights the relationship between installed cooling capacity and the coefficient of performance (COP). As cooling capacity increases, the COP improves, reaching a maximum of 3.7 at 32 tons. The current system, operating at 24 tons, has a COP of 3.64, demonstrating suboptimal energy efficiency. These results suggest that increasing cooling capacity would enhance performance, while further energy savings could be achieved through smart HVAC controls and improved ventilation strategies.

Table 1: Summary of Key Performance Parameters

Parameter	**Measured Value**	**Recommended Standard (ASHREA)**	**Deficit/Observation**
Airflow Rate (CMM)	119.1	127.35	8.25 CMM below standard
Cooling Load (tons)	24	31	7 tons deficit (22.5%)
Temperature Range (°C)	27 - 32	22 - 26	Above recommended comfort range
Humidity Levels (%)	60 - 75	40 - 60	Exceeds recommended range
Coefficient of Performance (COP)	3.64	4.0+	Moderate efficiency
Power Consumption (kW)	High	Optimized efficiency required	Excessive energy use

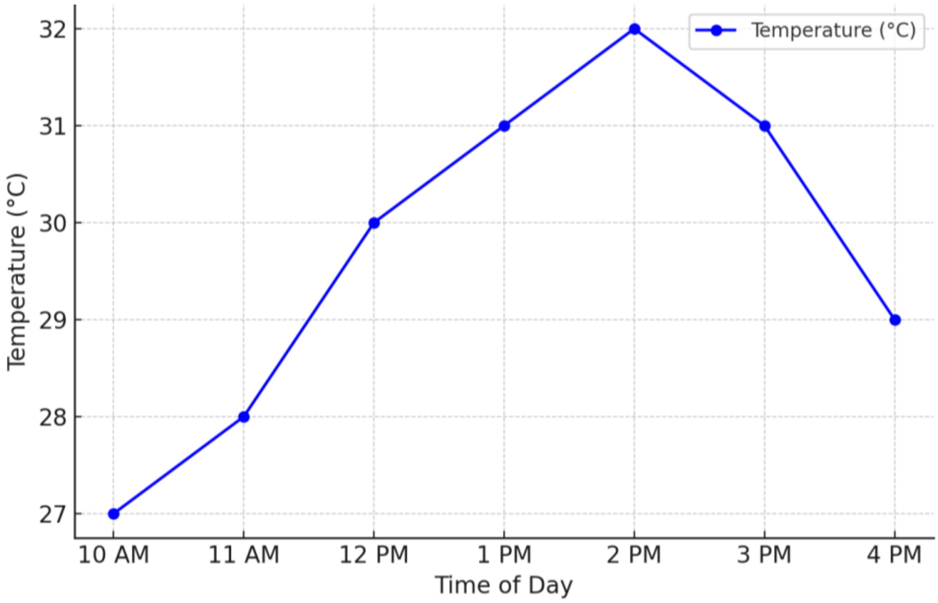

Figure 1: Graph of Temperature Variation in the Event Center

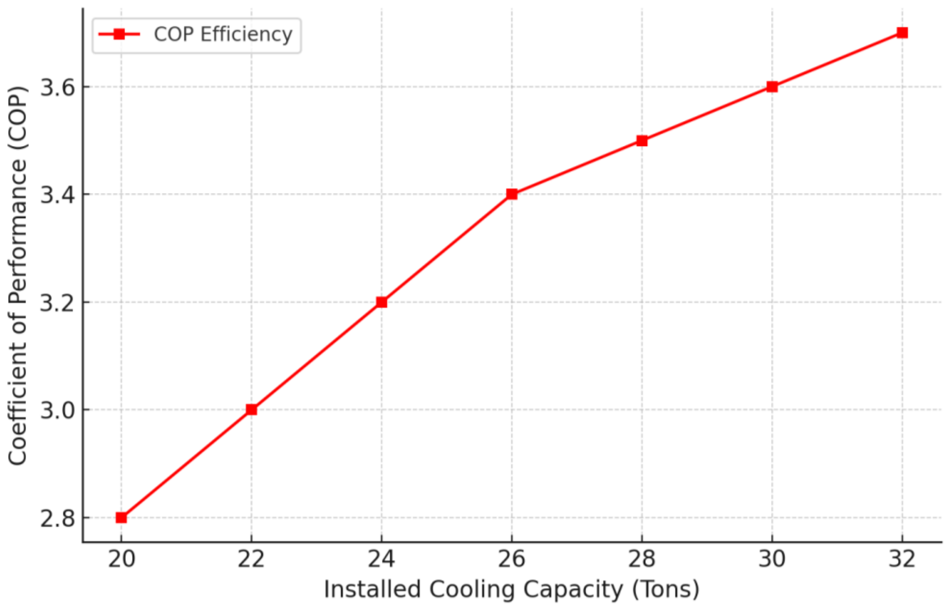

Figure 2: Graph of Energy Consumption and Efficiency Comparison

4.0 CONCLUSION AND RECOMMENDATION

The findings of this study emphasize the critical need for enhancing VAC systems in tropical environments like Benin City. The observed inefficiencies in airflow, cooling load, and energy consumption highlight the importance of optimized system design and control. Addressing these challenges through targeted interventions such as increasing cooling capacity, improving insulation, and integrating smart controls can significantly enhance thermal comfort and energy efficiency. Furthermore, periodic maintenance and adherence to international HVAC standards will ensure long-term sustainability. Future research should explore the integration of renewable energy sources to further reduce HVAC operational costs and environmental impact.

Recommendations include increasing cooling capacity, optimizing airflow, implementing smart HVAC controls, and improving insulation to enhance performance and reduce costs. Implementing these measures will improve comfort, reduce energy consumption, and enhance VAC system sustainability in tropical environments.

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