

## Research Article

# Smart Building Strategies for Seamless IoT Integration without Structural Remodelling: A Case Study on Dakkada Tower, Uyo, Nigeria

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## Article Info

**Keywords:** Internet of Things (IoT), IoT Integration, Smart Buildings, Building Retrofitting, Dakkada Tower, Energy Efficiency.

**Received:** 23.01.2026;

**Accepted:** 18.04.2026;

**Published:** 25.04.2026



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## Abstract

This study explores ways to integrate Internet of Things (IoT) solutions into existing structures without undergoing structural renovation, using Nigeria's Dakkada Tower as a case study. Retrofit feasibility was evaluated using a mixed methods approach that included a stakeholder survey (n=54) and energy simulations based on Python. The findings showed that comprehensive retrofits could save up to 27.7% in energy, while scenarios focused on lighting could save 10.4%. In addition to energy savings, adoption was significantly influenced by factors like improved security, greater control for tenants, and the need for education. The findings highlight problems specific to Nigeria, including erratic grid supplies, a deficiency in technical know-how (4.2/5), and ambiguous laws (4.2/5). The poll indicates that interoperability issues and rural connectivity limits make scalability more challenging (3.5/5). However, stakeholder preferences form incentives (38.9%) and Dakkada Tower's preinstalled smart elements suggest possible areas for targeted policy support. By aligning the proposed stepwise retrofit techniques with the Sustainable Development Goals of the UN, this study closes a vacuum in the literature on African urbanism. The results provide policy-relevant insights for frameworks such as NITDA's IoT plan and helpful guidance for facility managers, particularly with prioritizing occupant agency and data-driven analytics. Although it is not a one-size-fits-all solution, IoT retrofitting provides a scalable method of modernizing urban infrastructure in developing countries. With the right assistance and platforms that are driven by innovation, such as IoT West Africa, legacy structures can be changed to meet efficiency and sustainability goals.

## 1. Introduction

The rapid advancement of Internet of Things (IoT) technologies, on the other hand, is changing the way buildings are designed, managed, and experienced, from improving energy efficiency to improving security and user comfort [1, 2]. Smart systems based on the Internet of Things are becoming the backbone of modern infrastructure. This project will explore innovative strategies for integrating IoT solutions into existing buildings without messing with their core structural framework, using the Dakkada Tower as a case study. Dakkada Tower, a 21-story building located in Uyo, Akwa Ibom State, Nigeria, serves as an ideal case study for this research. This is because it is a modern architectural genius and a symbol of progress in the region [3, 4]. The tower represents a great opportunity to demonstrate the feasibility of retrofitting

IoT systems in existing infrastructure. It serves as a hub for business, entertainment and tourism [5, 6]. The building was commissioned in 2021 and has since become a landmark in the state. The tower features a 500-capacity parking lot, four elevators, emergency exits, fire protection sensors, and an aircraft wing. It includes advanced security systems such as card readers, biometric controls, and fire-protected doors. It also has state-of-the-art fire safety systems, LED lighting, and modern communication gadgets [7, 8]. In places like Nigeria, where cities like Uyo are preparing for smart upgrades, IoT could help with traffic, waste, and energy, tied to national pushes for better urban living [9]. By studying the current technological framework of the building and identifying integration opportunities, this research aims to propose cost-effective and scalable solutions that align with global smart building practices [10]. Smart buildings, which take advantage of IoT technologies, have become a key focus in modern architecture and infrastructure development. However, many existing buildings lack the necessary infrastructure for the integration of smart technologies to be feasible, and structural remodeling can be costly, time-consuming, very intrusive, and unsustainable [11, 12]. This challenge lays emphasis on the need for innovative strategies that increase the feasibility of seamless IoT integration without affecting the integrity and/or functionality of legacy buildings. This study provides valuable information on current practices and trends in the integration of IoT into existing buildings, without structural changes, with Dakkada Tower as a case study. Some of the most outstanding problems that directly or indirectly affect these efforts are outlined below:

- Legacy System Compatibility – Existing buildings often use outdated electrical, HVAC, and security systems that may not support modern IoT devices. This inadequacy automatically echoes the need for custom integrations [1, 12].
- Power Supply Constraints – Many IoT devices require a stable power source, but existing structures may lack adequate power outlets or provisions for battery-powered devices [9, 12].
- Security and Privacy Risks – New cybersecurity vulnerabilities are unearthed when retrofitting IoT, especially when integrating with legacy systems that lack robust security measures [1].
- Interoperability Issues – Different IoT devices and platforms may use varying communication protocols, making seamless integration difficult [1, 12].
- Scalability Limitations – Expanding or even integrating new IoT systems within an existing structure may require additional infrastructure, which could be costly or infeasible [12].
- Regulatory and Compliance Challenges – Buildings must adhere to industry standards and regulations, which could complicate IoT deployment without structural changes [11, 12].
- Environmental Constraints – Physical barriers such as walls, metal structures, or electromagnetic interference can disrupt IoT device communication [12].
- Cost Considerations – While avoiding structural remodeling reduces initial costs, integrating IoT into an existing building may still require significant investment in network upgrades, device retrofitting, and security enhancements.
- Device Placement Limitations – Without structural modifications, finding optimal locations for sensors, cameras, and other IoT devices can be difficult, potentially affecting performance.
- Integration with Building Management Systems (BMS) – If a building has an existing BMS, ensuring smooth communication between IoT devices and the BMS without conflicts can be challenging.
- Bandwidth Limitations – Older buildings may not have sufficient internet bandwidth to handle multiple connected devices, leading to network congestion.
- Interference from Existing Technologies – Legacy wireless systems, electrical wiring, and other RF-emitting devices may interfere with IoT connectivity, reducing efficiency.
- Structural Material Constraints – Thick walls, metal reinforcements, and certain building materials can block or weaken wireless signals, impacting sensor communication.
- Scalability Concerns – Future expansion of IoT systems may be difficult in an already constrained environment, requiring additional investments or creative workarounds.
- Energy Efficiency Optimization – Without structural changes, integrating energy-efficient IoT solutions (such as smart lighting or HVAC control) may have limited effectiveness if the building’s insulation, windows, or HVAC systems are outdated.

While there are various studies which explore the evolution and sustainability of smart cities in many different contexts, there is a noticeable lack of research with specific regards to Dakkada Tower and, for that matter, African high-rise buildings in general. Most existing research focuses on IoT implementation in newly designed smart buildings, and often tends to overlook the unique challenges and constraints associated with retrofitting existing structures. This study seeks to bridge these gaps by proposing and analysing strategies for seamless IoT integration into existing buildings, especially without requiring structural remodelling.

## 2. Related Works

The concept of smart buildings has gradually developed over time, pushing the limits of what is feasible in the real estate and construction industries, so it is not quite revolutionary anymore. As a result of the rapid advancement of technology, structures that integrate digital technologies to improve everything, from energy use to security and sustainability, have become more prevalent. It all began with the early Building Automation Systems back in the 1970s [13]. Traditionally, integrating smart tech onto older buildings meant big renovations - breaking down walls, rewiring everything - which was expensive, very intrusive, very messy, and often just not worth the hassle because these legacy setups weren't built with modern gadgets in mind. But things have become quite interesting over the years; recent leaps in the Internet of Things (IoT) have flipped the script, offering ways to retrofit without all that disruption. The very idea of integrating IoT devices into existing buildings seamlessly, no major remodeling required, is a game-changer for owners, tenants, managers, and even the wider community, for the following reasons:

1. It is a smart move for upgrading infrastructure quickly and painlessly. One can avoid disrupting daily life, spend less, and skip long downtimes [14]. For example, carrying out a full structural overhaul on a high-rise like Dakkada Tower would be a nightmare for the businesses that run in the building. The Internet of Things allows for the addition of real-time monitoring, automation, and data-driven adjustments that boost efficiency, comfort, and energy handling, all while leaving the building’s framework intact [15, 16].

2. For buildings like Dakkada Tower, which host a mix of offices and administrative work, this non-invasive approach is practical and easy to scale up, especially in taller or aging structures. Consider smart meters and wireless sensors being connected to existing infrastructure; this reduces installation hassles and enables managers to implement modifications in stages, depending on urgency or cost [17]. Additionally, the building can adapt to new technological trends and needs for greener operations because of IoT's flexibility.
3. It effortlessly agrees with bigger pictures like smart cities and sustainability. As one of the tallest towers in its region, the Dakkada Tower has the potential to enhance Uyo's status as a modern, innovative, and intelligent city. IoT pulls in real-time data for better energy adjustments, lower emissions, and smarter resource use [18, 19]. Making cities more livable in the face of growth and climate change is in line with international initiatives like the UN's Sustainable Development Goals. It even spurs employment and innovation, assisting in the direct combat of urbanization.
4. It boosts efficiency and reduces waste in professional setups like Dakkada Tower. Smart lighting with sensors for occupancy and light levels can curtail energy use, sometimes by 80% in the right places [20–22]. HVAC systems get smarter too, adjusting in real time with IoT data for comfort without consuming power [23]. Overall, this means improved occupant comfort, lower bills, and a smaller carbon footprint for the tower.

### A. Technologies Enabling IoT Integration:

The fundamentals include sensors that measure temperature, humidity, occupancy, and power consumption. For low-power, long-range conversations, they rely on wireless technologies like Wi-Fi, LoRaWAN, or Zigbee; ideal for buildings [24]. In confined areas, LoRaWAN excels, covering whole structures without the need for wires [25]. The data area is handled via fog and cloud computing. Fog for fast local processing to reduce latency, and cloud for large storage and computation [26]. Add big data and machine learning to analyze everything, optimize operations, and anticipate maintenance needs [24]. For example, predictive systems save time and money by using IoT data to identify errors early [27]. These can be retrofitted into older locations and tapped by biometrics and other security measures. Additionally, recent research emphasizes the use of IoT and deep learning for energy monitoring retrofits, increasing the precision of older buildings [28].

### B. Applications and benefits:

IoT can be applied in various areas with genuine benefits. Energy management systems can reduce usage by 30% and operating costs by 20% through automated controls for HVAC and lighting [26]. Occupancy sensors adjust settings based on presence, to save costs [29]. It also improves safety and comfort. IoT enhances security with smart locks and cameras and keeps interiors just right. Predictive maintenance reduces malfunctions [24]. Retrofits in highly used buildings promote sustainability over the medium term [30]. With no modifications, retrofitting replicates these successes. In Nigeria, as the country's cities grow, IoT could improve building safety, including fire detection [31].

## 3. Methodology

The aim of this section is to bridge the theory so far with real-world applications, and address key challenges such as energy efficiency and the extent to which integration is attainable in a developing context like Nigeria.

### 3.1. Research Design

This research adopts a mixed-methods design because the concept of IoT retrofitting is not just about the technology. It involves people, costs, and real buildings too. Quantitatively, we maximized the hard numbers, like energy loads and savings percentages, and for qualitative analysis, we collected opinions and challenges, as highlighted in similar studies of smart building technologies [13, 14]. This approach lets me cross-check and compare findings: for example, if the simulation shows large savings, but the survey suggests otherwise, that highlights where there might be faults in practice. I drew a few parameters (such as power factors, demand factors, lighting/sockets/HVAC load densities per m<sup>2</sup>, operating hours for annual energy estimates, and diversity factors for commercial buildings) from Nigerian standards, like those from the Nigerian Electricity Regulatory Commission (NERC) and the Federal Ministry of Housing and Urban Development (FMHUD), in order to ensure compliance with local electrical and building practices, and global IoT literature, to keep it realistic.

### 3.2. System Model

**This study uses a simulation-only system model:** No physical IoT hardware was deployed. The model is a logical representation of building energy as implemented in Python, using Google Colab. It describes inputs, processing steps, scenarios and outputs used to evaluate the effect of IoT-enabled control strategies on energy consumption.

**Inputs and parameters:** The model uses building and operational parameters as inputs: floor area = 5000 m<sup>2</sup>, operating hours = 2500 hours/year, and a demand factor = 0.8. Category loads (kW) were aggregated from prior load-takeoff: lighting load = 124.0 kW (74.4 + 49.6), socket load = 133.3 kW (65.1 + 18.6 + 37.2 + 12.4), HVAC load = 330.2 kW (228.6 + 101.6), and other load = 9.5 kW (5.7 + 3.8). These produce a baseline total (kW) and baseline annual energy in kWh/year via load × operating hours × demand factor.

#### Core computation (processing)

The model computes post-retrofit loads by applying literature-based savings multipliers per category:

- lighting savings = 0.50
- socket savings = 0.15
- HVAC savings = 0.25

- other savings = 0.10

Two scenarios are evaluated:

- Scenario 1 (Lighting-focused): applies lighting savings only.
- Scenario 2 (Full IoT): applies savings to lighting, sockets, HVAC, and other loads.

For each scenario the model:

1. Computes post-category loads (kW) = baseline category  $\times$  (1 savings category).
2. Sums post category loads to get post total (kW).
3. Converts to annual energy: post annual = post total  $\times$  operating hours  $\times$  demand factor.
4. Derives energy saved (kWh/year) = baseline annual post annual and energy percent saved.

### Sensitivity analysis

To test the robustness of Scenario 2, the calculated energy savings are varied within a  $\pm 10\%$  range using scaling factors from 0.9 to 1.1.

#### Outputs and presentation: The model outputs:

- Tables showing baseline and post-retrofit category loads, created with Pandas DataFrame.
- A summary table of post annual energy and energy saved for each scenario.
- Console printouts for baseline total, baseline annual, post totals per-scenario, and percent savings.
- Visualizations created with Matplotlib: outputs include a baseline load distribution (pie chart), total load comparison across scenarios (bar chart), and sensitivity analysis (line chart).

### Implementation notes

The simulation was implemented in Python using NumPy (numerical operations), Pandas (tables), and Matplotlib (plots) and executed in Google Colab. The calculation logic is encapsulated in a small helper function calculate annual(load, hours, factor) and explicit scenario blocks, making the model reproducible and easy to adjust for different parameter values.

**Limitations:** The system model is deterministic and singlenode. This means it does not account for random occupancy variations or dynamic HVAC behavior. The savings rates are derived from literature-based assumptions and are used as scenario inputs rather than measured performance data.

### 3.3. Survey Tool

We created a survey, using Google Forms, to gather thoughts and observations from stakeholders and in Nigeria's building sector. It contained 29 questions, combining Likert scales (1-5 for agreement levels), multiple-choice questions for qualities like top benefits, and open-ended questions for comments. The questions covered familiarity with IoT, perceived/expected benefits (e.g., energy reduction, comfort), challenges (e.g., costs, security), and future outlook. For analysis, We used Pandas in Python for statistics: means and standard deviations for scales, frequency counts for categorical items. For multiselect checkboxes like devices that respondents were aware of, security/biometric controls topped the chart at 63% awareness. Open responses were thematically grouped (e.g. "enhanced comfort" kept popping up).

### 3.4. Simulation Modelling

For quantitative analysis, We built a Python model in Google Colab to simulate energy loads and IoT savings.

#### Key parameters

- Floor area: 5,000 m<sup>2</sup> (estimated for 5 offices in a high-rise like Dakkada).
- Operating hours: 2,500 annually (based on NERC guidelines for commercial operations, assuming 5 days/week) [32, 33].
- Demand factor: 0.8 (NERC standard for commercial buildings) [34, 35].
- Baseline loads (aggregated in kW): Lighting (124), sockets (133.3), HVAC (330.2), and other (9.5), totaling 597 kW, derived from typical office configurations in Nigerian high-rises [17].

#### Savings estimates came from literature review

50% for lighting (occupancy sensors), 15% sockets, 25% HVAC, 10% other systems [13, 18]. Annual energy = load  $\times$  hours  $\times$  demand factor.

#### Scenarios:

- Baseline: No IoT.
- Scenario 1: Lighting only.
- Scenario 2: All categories.

### 3.5. Added sensitivity

We used NumPy for linear spacing, and a sensitivity analysis varied the savings multipliers for Scenario 2 from 90% to 110% in 5% increments.

**Outputs/Visuals:** We included tabular summaries for load breakdowns, and used a pie chart for percentage breakdown, bar chart for comparisons, line graph for sensitivity, all generated with matplotlib and exported as images.

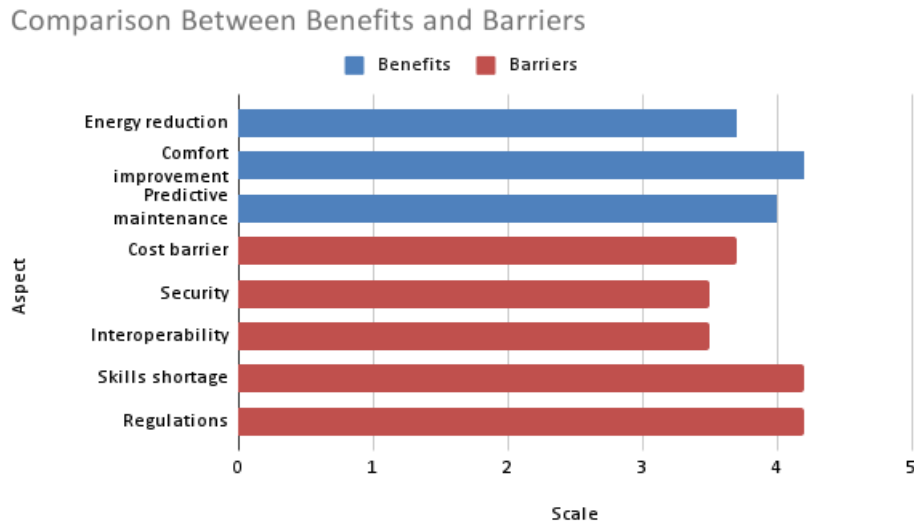


Figure 1: Comparison Between Benefits and Barriers.

## 4. Results and Discussion

This section presents the results of the materials and methods adopted throughout this research; the survey perspectives, simulation numbers, and how they are all connected. The patterns are exciting, from how much people love and would embrace the idea of IoT integration into existing buildings, to the impediment which their optimism faces on the grounds of cost and power outages. The results of these methods will determine the feasibility and scalability of retrofitting IoT into existing buildings without structural modifications. The results are discussed in relation to the objectives of the study.

### 4.1. Survey Findings

A total of 54 respondents participated in the survey:

- Building Occupants/Tenants 57.4%
- Engineers/Architects 13%
- Facility Managers 7.4%

As regards the number of years of experience in the building/real estate industry:

- 5 years experience 57.4%
- More than 20 years 16.7%
- 5-10 years 13%
- 11-20 years 13%

As regards the type of building where they primarily work or reside:

- Residential 77.8%
- Institutional (e.g., hospital/school) 11.1%
- High-rise commercial/office 7.4%

Knowledge of IoT: 2.8/5 average. Involvement in IoT retrofit project in already existing buildings: 37% Optimism about Integration: 3.7/5 average. Perceived benefits averages (5):

- Energy cut: 3.7
- Comfort: 4.2
- Predictive Maintenance: 4.0
- Smart city: 3.6
- Operating expenses drop: 3.8
- Electrical operations: 3.8

Top perks:

- Occupant comfort 75.9%
- Energy savings 64.8%
- Enhanced security 64.8%
- Scalability 38.9%
- Sustainability 22.2%.

Expected improvements:

- "Energy optimisation"
- "Enhanced security"
- "Occupants comfort"

Perceived barriers averages (5):

- Costs: 3.7
- Security: 3.5
- Interoperability: 3.5
- Skills: 4.2 (Especially in Nigeria)
- Lack of Regulatory Standards: 4.2
- Integration: 3.6

Connectivity:

- Compatibility 57.4%
- Disconnects 38.9%
- Scalability 27.8%
- None 18.5%

Recommendation likelihood: 4.2/5. Willingness boosters:

- Affordable devices 79.6%
- Security 66.7%
- Proven case studies 48.1%
- Government incentives 38.9%

5-year standard:

- Maybe 44.4%
- No 29.6%
- Yes 25.9%

Scalability: 3.6/5

**Table 1: Key survey averages**

Aspect	Average (1-5)
IoT knowledge	2.8
Integration feasibility	3.7
Energy reduction benefit	3.7
Comfort improvement	4.2
Predictive maintenance	4.0
Cost barrier	3.7
Security	3.5
Interoperability	3.5
Skills shortage	4.2
Recommendation likelihood	4.2
Scalability	3.6

**Table 2: Top benefits frequencies (%)**

Benefit	%
Energy efficiency/cost savings	64.8
Improved comfort	75.9
Enhanced security	64.8
Sustainability	38.9
Scalability	22.2

## 4.2. Simulation Findings

**Baseline:**

- Total = 597 kW (HVAC 55.3%, lighting 20.8%, sockets 22.3%, other 1.6%).
- Annual = 1,194,000 kWh.

**Scenario 1 (Lighting-focused):**

- Post-Retrofit Load: 535.0 kW

- Post-Retrofit Annual Energy: 1,070,000 kWh/year
- Energy Saved: 124,000 kWh/year (10.39%)

**Scenario 2 (Full IoT):**

- Post-Retrofit Load: 431.5 kW
- Post-Retrofit Annual Energy: 863,010 kWh/year
- Energy Saved: 330,990 kWh/year (27.72%)

**Sensitivity:**

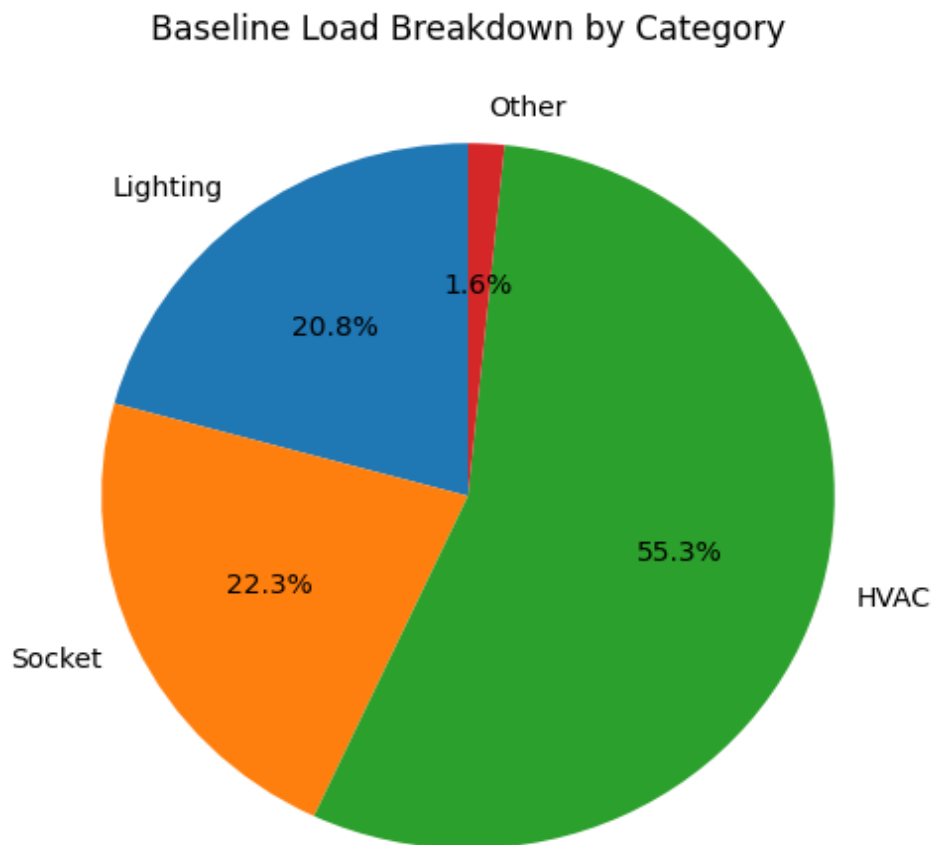
- At 100% multiplier, 330,990 kWh saved
- Ranges 248,400-303,600 kWh.

**Visuals (described):**

- The Pie Chart shows HVAC dominance.
- The Bar chart drops from baseline to scenarios.
- The Line Graph rises linearly with the multiplier.

**Table 3: Load breakdown (kW)**

Category	Baseline	Scenario 1	Scenario 2
Lighting	124.0	62.0	62.000
Socket	133.3	133.3	113.305
HVAC	330.2	330.2	247.650
Other	9.5	9.5	8.550
<b>Total</b>	<b>597.0</b>	<b>535.0</b>	<b>431.505</b>



**Figure 2: Baseline Load Breakdown by Category**

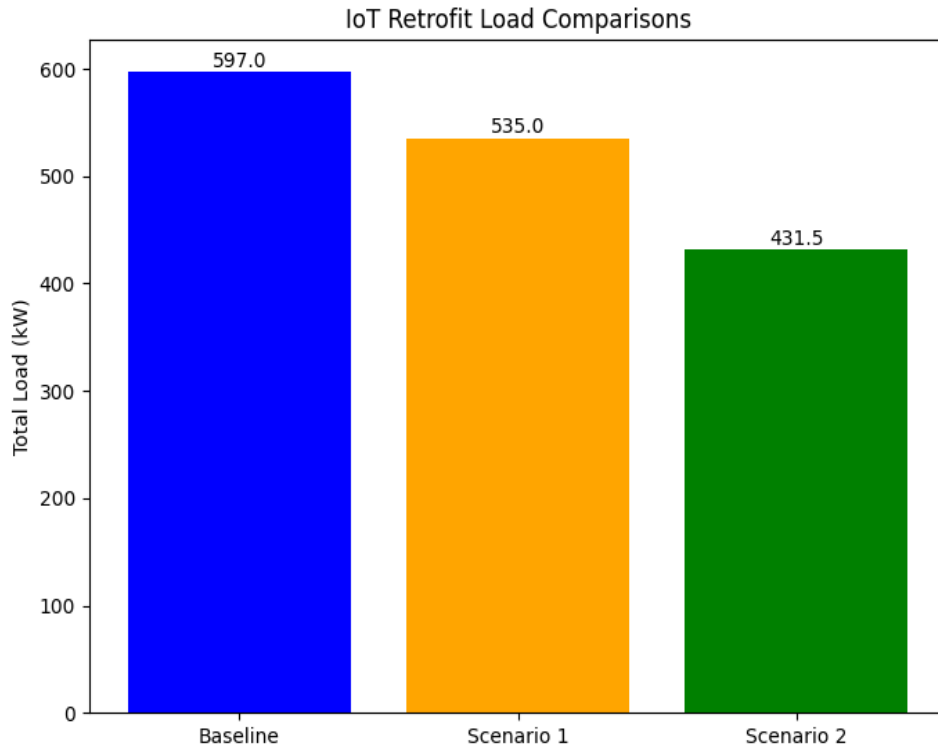


Figure 3: IoT Retrofit Load Comparisons.

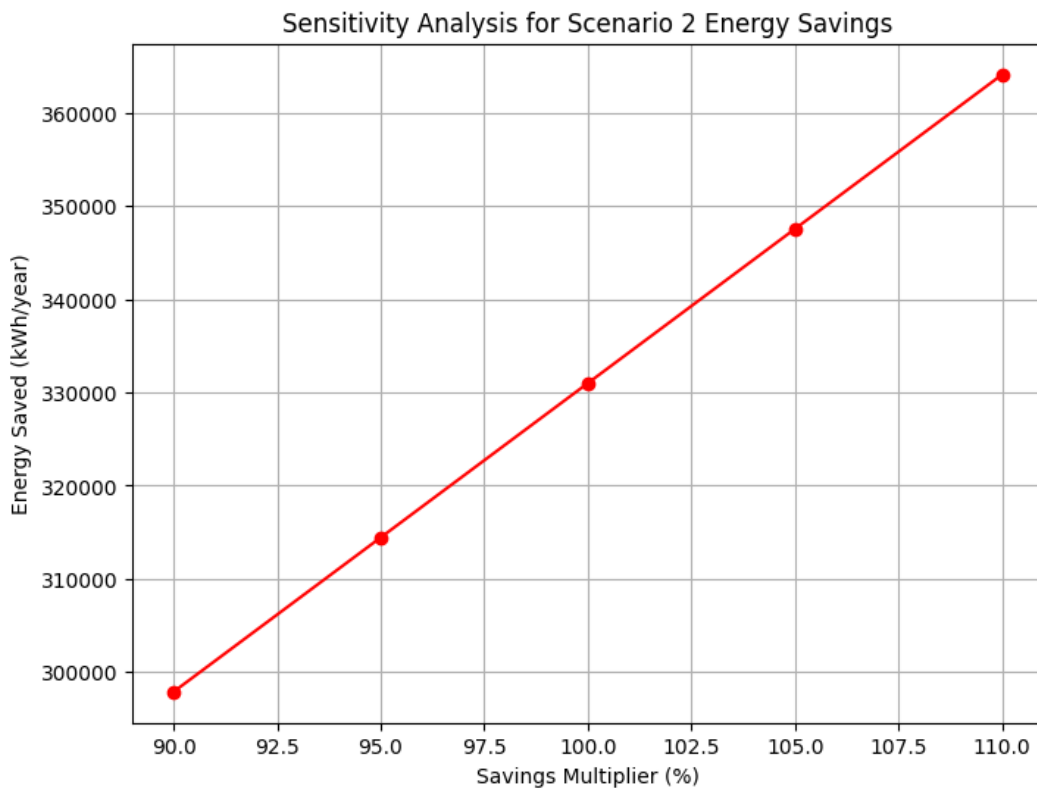


Figure 4: Sensitivity Analysis for Scenario 2 Energy Savings.

The survey results are consistent with global literature: Benefits like predictive maintenance (4.0/5) match literature with 15–50% savings [1, 2], but Nigeria-specific issues (skills 4.2/5, regulations 4.2/5) align with infrastructure challenges [19, 21]. While the Dakkada Tower may be ideal for retrofitting, simulations assume stability, and unstable grids could negatively affect saving [4]. High costs (3.7/5) agree with retrofits needing 15% budget, but a long-term drop in operating expenditure (3.8/5) could balance it [20]. Security concerns (3.5/5) highlight cyber risks, common in IoT [21]. Simulations support the literature on full IoT by demonstrating the possibilities of Scenario 2 (27.72%) [18]. But, sensitivity results suggest that a 10% decline could reduce projected savings to 20%. In general, IoT aligns with Nigeria’s goals for

smart development, but government incentives are needed for its adoption. The technology is regarded as scalable (3.6). However, opinions on the viability of a five-year norm are still divided.

## 5. Conclusion

We have reviewed existing literature, adopted a few methods of analysis, and arrived at results to draw some solid conclusions, offered a few practical recommendations, and considered future explorations. It has been quite fascinating to see how stakeholder opinions and simulated data potentially align, in spite of real-world limitations in the Nigerian context. In the future, to translate these insights into action, several steps stand out. First, policymakers should prioritize incentives, such as subsidies for affordable IoT devices, drawing from NCC's recent studies on next-gen networks. Facility managers at sites like Dakkada Tower could start with phased pilots, focusing on high-impact areas like lighting (10.4% simulated savings) before rolling out fully, incorporating modern wireless communication methods (like Wi-Fi, Zigbee, LoRaWAN, or Bluetooth) to avoid the problems of old cabling and hardware. Training initiatives are essential: By working with organizations like IoT West Africa or NITDA programs, the 4.2/5 skills gap can be addressed and stakeholders provided with knowledge on cybersecurity and interoperability (3.5/5). While retrofits use tools like BIM-digital twins for seamless integration, developers should prioritize standards-compliant designs in new high-rise constructions. Finally, continuous observation may be able to track actual savings and improve strategies, guaranteeing that IoT promotes environmentally friendly urban growth.

## Article Information

**Disclaimer (Artificial Intelligence):** The author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.), and text-to-image generators have been used during writing or editing of manuscripts.

**Competing Interests:** Authors have declared that no competing interests exist.

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