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User's perception of smart technologies in buildings in Lagos State

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Abstract
The integration of smart technology into buildings has become a major trend in urban development. As a major urban developing area in Nigeria, Lagos State presents a dynamic environment for the adoption and perception of smart technology in buildings. The study encompasses a comprehensive analysis of the benefits, challenges, and implications of smart technologies in buildings, as well as the potential impact on user experience. The objectives of this research are to investigate users awareness and knowledge of smart technologies, examine users' experiences and satisfaction levels with existing smart building solutions as well as identify challenges and concerns influencing users perceptions of smart technologies in buildings in the state. This research aims to investigate the user's perception of smart technology in buildings within Lagos State through the use of surveys. The findings from this research showed that though there has been a bit of lack of awareness about it, majority of the Lagos residents embraced the idea of smart buildings and it was recommended that more awareness should be done.

Keywords: Lagos State, smart technology, smart design, sustainability, user perception, urban development

Introduction

The rapid urbanization and technological development in Lagos State have led to increased interest in smart building solutions. This urban development is due to some major factors such as population growth, rural-urban migration, and economic opportunities which has led to increased demand for infrastructure, including buildings, to accommodate the rising population.. The combination of the urban development and technological evolution has heightened the interest in smart buildings in Lagos State. Stakeholders, including developers, policymakers, and building users, are increasingly exploring the potential benefits of implementing smart technologies to improve building efficiency, sustainability and user experience. The Smart technology offers these numerous benefits in terms of energy efficiency, security, comfort, convenience, and sustainability which are major needed factors in the ever-growing metropolis of Lagos.

As buildings become more intelligent and interconnected, it is important to understand the perception of users towards these technologies. Understanding users perception involves studying how individuals, communities and organizations in Lagos State perceive, accept, and interact with smart building technologies. It is very crucial due to the fact that different cultural norms, values and social structures shape how each individual perceives and embraces technological innovations, including smart building technologies. It also involves identifying the needs, preferences and expectations regarding smart building technologies as well as the economic and environmental factors such as energy savings and cost efficiency. Studying the usability, accessibility and user interface of the buildings also matter as well as identifying any barriers or challenges users encounter when engaging with these technologies in the environment.

This research aims to address the user's perception of smart technology integration in buildings within Lagos State, shedding light on the opportunities and challenges associated with the adoption of these innovative solutions.

Literature Review

Smart Technology in Buildings

(Ismail et al. 2019) [1] Intelligent building concepts are not recent developments from an architectural perspective. Even in primitive and indigenous architectural forms, there were advanced instances of clever design. These designs showcased intelligence through the symbiotic relationship between occupants and the technologies embedded in the built environment. This close connection was intentionally integrated into the structure, enabling users to engage with various systems. Users possessed the capability to modify, adjust, and customize the building in response to changing circumstances, be they social, functional, or related to natural phenomena. The achievement of comfort, utility, and satisfaction depended on the user's ability to manipulate the architectural form. In this context, the occupant played a crucial role in both the design and utilization of the building. The absence of the occupant rendered the building non-functional and devoid of any intelligent features. The ongoing interaction between the user and the building, including its technologies, was dynamic and responsive, representing a form of intelligent architecture as outlined by Walter M. Kroner in 1989. This perspective underscores the historical and fundamental connection between occupants and the inherent intelligent design in architectural structures. The evolving relationship between users and the technologies integrated into contemporary buildings demonstrates a more complex and dynamic integration compared to the intelligence observed in primitive smart buildings.

A smart building is a structure that incorporates various systems, including lighting, HVAC (heating, ventilation, and air conditioning), voice and data communications, and other building functions. These systems are integrated to efficiently manage resources in a coordinated manner. The objective is to enhance tenant performance, optimize investments, achieve cost savings, and improve overall flexibility within the building. Smart buildings utilize technology and automation to create a seamless and efficient environment that responds to the occupants' needs and contributes to sustainable and resource-efficient operations (The National Research Council, Washington DC).

According to Ismail's 2019 definition, a smart building is identified as an "electronically enhanced building." The description goes on to elaborate that a smart building is fully equipped with controllers and systems, complemented by a robust infrastructure, to facilitate the utilization of cutting-edge communication, data processing, and control technologies by both its inhabitants and operating staff. This type of building includes essential infrastructure elements such as wires, cables, conduits, power supply, heating, ventilation, cooling, lighting, sound insulation, and security systems. The primary goal is to support the performance requirements of modern office environments. Essentially, a smart building incorporates advanced technologies to improve communication, data processing, and control, benefiting both occupants and operational staff.

The incorporation of smart technologies into buildings signifies a significant transformation in their design, operation, and the way users experience the built environment. From sensor systems driven by the Internet of Things (IoT) to sophisticated data analytics and automation platforms, smart technologies are reshaping how buildings operate and how occupants engage with their surroundings. This comprehensive integration of technology holds the potential not only to optimize building efficiency but also to significantly enhance the user experience within the built environment.

Technologies involved in the integration of a Smart Building (Features)

- **HVAC Systems:** Smart HVAC systems utilize a variety of sensors to oversee and manage their performance. Such systems use software to analyze information from different sensors to enhance the system's efficiency and the comfort level of those within the building. Advanced HVAC controls have the capability to lower energy use in areas that are not in use, detect and troubleshoot issues, and decrease the operation of HVAC systems, especially during times of high energy demand.
- **Lighting:** Intelligent lighting systems come with enhanced features, including natural light utilization and progressive controls for occupancy detection and dimming, to prevent excessively bright areas. Lighting fixtures with adjustable brightness settings are evolving quickly, with demand-response initiatives promoting both incremental and smooth dimming options. These setups offer wireless management and can be integrated into lighting control platforms, allowing users to operate them via online dashboards.
- **Plug Loads:** Intelligent plug load controls help manage the energy use of various portable and ad-hoc devices in buildings. In established structures, these systems consist of smart receptacles and power strips that can shut off electricity to inactive equipment based on timers, motion detectors, or usage monitoring. Some smart strips can detect a main device, like a desktop computer, and control connected ancillary gadgets accordingly. These load schedules can also be integrated with lighting and building management systems for centralized governance, enhancing energy economy and streamlining building operations.
- **Window Shading:** Smart window systems are designed to regulate solar heat and daylight entering the building. These systems include both passive and active window glazing and films responsive to changes in sunlight or temperature. Additionally, auto-controlled shades operate on specific schedules to manage light levels and solar heat gain. In retrofitting, smart shading technologies prove particularly effective in buildings with untinted, single-pane windows.
- **Automated System Optimization (ASO):** Adaptive Systems Optimization (ASO) challenges traditional Building Automation Systems (BAS) by harnessing real-time feedback rather than static schedules. ASO utilizes Information and Communication Technology (ICT) to gather and scrutinize data on energy use and system function within a building. It preemptively adjusts settings in response to changing variables like occupancy trends, weather predictions, and fluctuating utility costs. Cloud-powered remote observation of buildings is becoming commonplace in ASO application, facilitated by web-based energy management interfaces, which allow for more dynamic and responsive building management.
- **Human Operation:** Smart buildings enable operators to interact with systems via intuitive computer dashboards. These interfaces present clear views into building functions and energy consumption, centralizing data

analysis and offering alerts to issues flagged by Automated System Optimization (ASO). Staff, including IT experts, use training in network management, data analytics, and advanced smart tech. Occupants have mobile apps to personalize workspace settings like lighting. These apps also show individual energy use and suggest efficiency tips. This tech blend boosts building efficiency and augments occupant comfort.

- **Distributed Energy Resources (DER):** Distributed Energy Resources primarily include energy generation and storage systems strategically placed at or near the point of use, providing power independently of the grid. Examples of DER encompass combined heat and power, solar photovoltaics, other renewable sources, as well as battery and thermal storage. DER relies on communication and control devices for efficient energy dispatch, and integrating a smart inverter to the DER adds smart functionality. Smart inverters are software-controlled devices that enhance the management of onsite energy generation and storage. They facilitate continuous two-way communication between the DER and the electric grid, allowing for immediate responses to load signals, electricity rates, demand response events, and power outages. The incorporation of smart inverters enhances the responsiveness and adaptability of DER systems, contributing to a more efficient and resilient energy infrastructure.

Benefits of Smart Technology in Buildings

The incorporation of smart building technology in the construction industry of developing countries brings numerous benefits to professionals, clients, and the nation as a whole. Vattano emphasizes that the use of smart buildings in sustainable construction contributes to minimizing waste, efficiently utilizing resources, and reducing environmental harm. According to (Honeywell et al., 2015) [1], the economic advantages of smart buildings over traditional structures include a swift return on investment, avoidance of appliance and equipment failures, prevention of fire outbreaks, and addressing energy challenges. (Balta-Ozkan, et al., 2014) [2] point out the social benefits of smart buildings, including concerns related to safety, healthcare management, and security. (Sherif, et al., 2018) [10] identify general benefits, such as reducing energy costs, increasing staff productivity, improving building operations, providing web-based security, and enhancing the safety and security of occupants. Additional advantages encompass health and safety, data infrastructure connectivity, fault detection in the system, and cost savings (Honeywell et al., 2015) [7]. Overall, the adoption of smart building technology yields a range of advantages across economic, social, and environmental dimensions.
(Ejidike, et al., 2023) [5] have distilled these benefits into five major categories;

- **Energy Saving:** Smart building technologies play a crucial role in enhancing energy efficiency and maximizing savings throughout the building's operational lifespan. As per a study by (Iwuagwu U et al), smart buildings ensure real-time control and monitoring of energy consumption within the building, contributing to its overall environmentally friendly attributes. Noteworthy contributions to energy savings have been reported, with smart buildings reducing power consumption significantly in documented cases, such as a 34.78% reduction from 765,228.16 to 499,067.01 kWh. This evidence underscores the positive impact of smart building technologies in optimizing energy usage and promoting sustainability.
- **Safety and Security:** As noted by (Honeywell et al., 2015) [7], safety and security systems within smart buildings cover diverse aspects, including responses to threats, access management, protection of lives and assets, and ensuring occupant comfort and productivity. These systems encompass factors like illumination, thermal comfort, air quality, connectivity, and energy availability. Whether residential or commercial, the prioritization of safety and security in smart building technologies is essential. Designing and implementing these technologies must consider ensuring comprehensive safety and security measures for occupants.
- **Maintenance Cost-saving:** Extending beyond initial construction costs, smart buildings, as highlighted by (Iwuagwu, et al.) and (Ejidike, et al., 2023) [5], consider operating and maintenance costs over the building's entire lifecycle. Automated control, communication, and management systems improvement can lead to cost savings by allowing equipment to be shared among multiple users. By integrating safety, sustainability, and productivity, smart buildings create more interconnected, dynamic, and functional systems that contribute to cost savings beyond maintenance alone.
- **Improve Building Comfort:** According to (Buckman, et al., 2014) [3], smart buildings are significant in enhancing occupant comfort through systems that interpret data from previous usage, adapting to occupants' preferences. Optimization of lighting, utilities, and Heating, Ventilation, and Air Conditioning (HVAC) systems aligns with occupancy patterns and desired comfort levels. Real-time monitoring of building systems in smart buildings optimizes energy usage, leading to minimized asset loss and increased comfort for occupants.
- **Productivity and Collaboration:** Lighting plays an important role in smart building technology, influencing occupants' well-being, motivation, and productivity, as noted by (Buckman, et al., 2014) [3]. Integrated systems not only improve the quality of life for occupants but also contribute to increased sustainability, safety, and overall productivity in smart buildings.

Integration of Smart Technology in Buildings

The incorporation of smart technology into buildings signifies a groundbreaking shift in our approach to conceptualizing, designing, and engaging with the built environment. Smart buildings, featuring a multitude of interconnected devices and systems, are strategically designed to elevate efficiency, comfort, and sustainability. The integration of smart technology in buildings offers a fresh perspective on how structures are constructed, utilized, and maintained.

Methodology

Research Method and Instrument adopted for this study

The research employed a quantitative methodology, utilizing a random sampling technique to select residents from various age groups in Lagos State, focusing on six specific Local Government Areas (LGAs). Lagos State was chosen for its technological exposure and recent innovations, situated in

Nigeria's south-western region. Geographically, it is located between latitudes 6° 20'00" N and 6° 40'0" N, and longitudes 3° 20'0" E and 4° 20'0" E, covering an approximate area of 3,496 km2. With a population of around 14 million people and 20 Local Government Areas, Lagos State experiences an annual population growth of 5.7%, making it one of the world's fastest-growing megacities.

The study's sampling frame involved randomly selecting residents from six specific local government areas out of the total twenty in Lagos State. This selection was based on the prominence of technology-oriented buildings in these areas. Equal representation from each local government area aimed to ensure a statistically balanced sample of the population. This selection strategy is crucial to the study, as it will use questionnaires to gather diverse perspectives from different individuals on the integration of smart technology in buildings.

Data Collection Procedure

A total of 593 questionnaire forms were distributed to selected respondents within the six local government areas in Lagos State, both at their homes and offices. Out of these, 439 completed forms were retrieved, resulting in an overall response rate of 88%. Upon review, 400 of the retrieved questionnaires were deemed relevant and suitable for analysis. These local government areas were selected based on their association with a significant presence of technology-oriented buildings, contributing to the study's focus on the integration of smart technology in the built environment.

Table 1: Yamane Formula was applied to each LGA to determine the sample size used to distribute the questionnaire

Local Government Area	Population	Sample Size
Surulere	504,409	100
Lagos Mainland	317,980	98
Ikeja	313,333	99
Eti-Osa	287,958	99
Lagos Island	209,665	99
Ibeju-Lekki	117, 542	99

Findings and Discussion

In this section, the analysis results and a discussion of the findings pertaining to the research questions on awareness, residents' findings, and preferences regarding current smart buildings in Lagos State are presented.

Awareness

A simplified definition of a smart building was provided and the awareness question followed, inquiring if the respondent had ever stepped into a smart building. 66.7% gave a negative response, 20 % gave a positive response that they have been in one while 13.3% said they think they have been to a smart building. The second question was linked to the first which buttressed the point of if the respondent will be willing to step into a smart technology building. The response was a 100%.

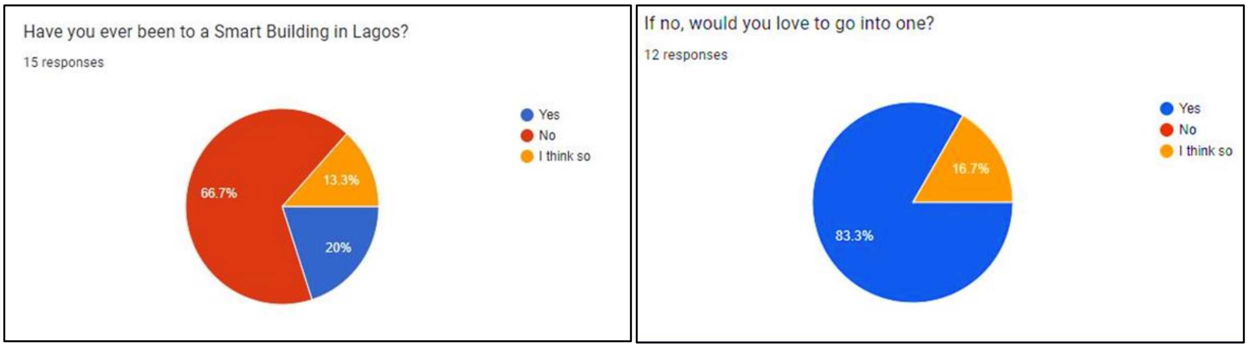

Fig 1 and 2: Pie-chart showing the data respondents

Section II

The second section of the question was directed to the respondents who responded positively about stepping into a smart technology building. A checkbox was created to tick any of the features they noticed when they visited the smart building. A table would be shown of the percentage that noticed each feature listed in the questionnaire. A question was also asked inquiring about how well they enjoyed the experience.

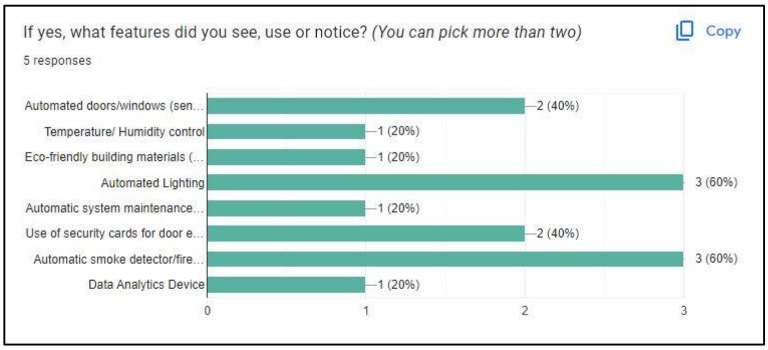

Fig 3: A Bar Chart showing the features the respondents noticed in the smart building

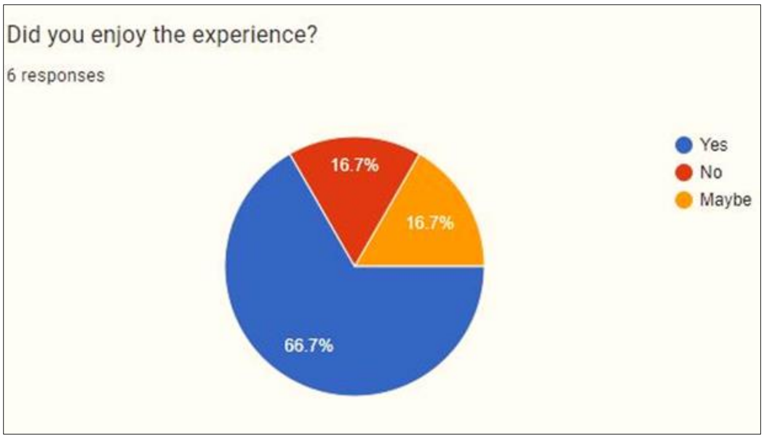

Fig 4: Pie Chart showing the data of the respondents from section II

Section III

This section asked the respondent if the experience was enjoyable and if they would love to see more buildings like it in their Local Government Area. It was a very positive response as every respondent gave a Yes.

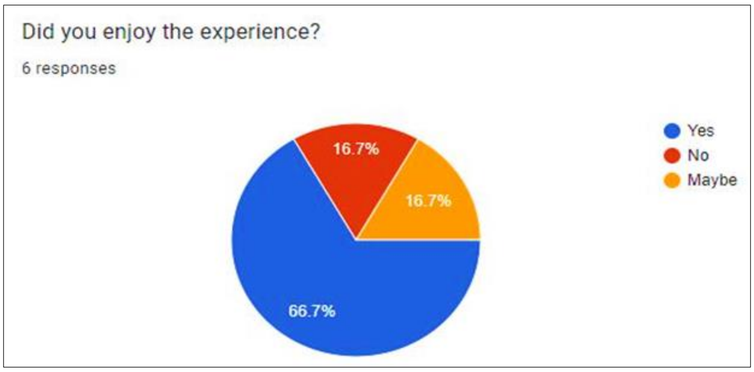

Fig 5: Pie Chart

Conclusion and Anticipated Findings

The study delved into the perceptions of Lagos residents regarding smart technology in buildings, shedding light on the awareness levels among the population. It uncovered that a significant portion of residents lacks awareness of smart buildings, with many not having experienced one. The hypothesis results indicated that those who have encountered smart buildings generally enjoyed the experience and expressed a desire for more such developments in Lagos State.

In conclusion, the limited presence of smart buildings in Lagos has contributed to low awareness levels among residents. To address this, the study recommends organizing seminars and awareness programs, especially targeting the building industry, to educate residents about the benefits of smart buildings and how they can enhance living standards. Increased awareness could lead to improved safety, energy efficiency, cost savings, and environmental protection by reducing greenhouse gas emissions.

Furthermore, the building industry plays a crucial role in promoting smart buildings. The study suggests that the industry should offer smart building solutions to clients and the government, thereby reducing the construction of traditional buildings in the state. This can be achieved through training sessions, workshops, conferences, and seminars, creating a knowledge base for the development of smart buildings.

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