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The influence of information and communication technology (ICT) on stakeholders' involvement and smart urban sustainability

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ABSTRACT

It is impossible to overstate the role that smart cities and the building resilience strategy play in the movement toward environmental sustainability, particularly in industrialized and developing nations. There has been a rise in the use of efficient systems to enhance built environment control and accomplish infrastructure development projects, and for this to be successful, countries around the globe, including Nigeria, need robust smart cities and buildings. Few researchers have looked at how smart cities and building projects might improve the sustainability practices of Nigeria's built environment in the context of environmental issues. The major research aim of this study is to investigate the role of Information and Communication Technology (ICT) in advancing urban sustainability in the context of Lagos, Nigeria, amidst the city's rapid population growth and the implementation of smart city projects. The study's research questions include the following: First, How can information and communication technology (ICT) be leveraged to support the development of urban sustainability? Secondly, what is the impact of ICT on stakeholders' involvement and participation in urban sustainability? Thirdly, how can stakeholders' involvement and participation impact urban sustainability? Structural equation modeling using partial least squares (SmartPLS 3.0 Edition) as an analysis tool was used to assess the suggested model and the empirical study results in support of all the hypothesized associations. Results revealed that Information and Communication Technology (ICT) is positively associated with smart urban sustainability. Also, a positive and significant influence of ICT on consolidating stakeholder involvement and participation is paramount. Lastly, smart city and building initiatives have the potential to significantly improve urban sustainability. The implication of the study enables the possibility to optimize the impact of an ICT-based urban environment, thereby creating sustainable and resilient communities that meet the needs and priorities of all members of society.

1. Introduction

In recent years, there has been in-depth attention and research on Information and Communication Technology (ICT) and smart urban sustainability around the world (Kutty et al., 2020; Agunbiade et al., 2021; Lee et al., 2023). This is with a view of leveraging technology to improve urban infrastructure, enhance livability, and promote sustainability. Among the key enablers of a smart urban environment is information and communication technology (ICT), which provides the tools needed to collect, analyze, and disseminate data on various aspects of urban life (Lövehagen and Bondesson, 2013). The importance of ICT in global urban sustainability cannot be overstated. Any country's economic growth and progress are inextricably linked to its engagement in the creation, acceptance, and inventive application of technology innovations (European Commission 2010a; Gouvea et al., 2017; Lee et al., 2023). Given this, successful ICT implementation and utilization can boost the level of creativity in the urban environment. Although ICT connects the many parts of sustainable development, it improves the interdependence of economic growth and society's interconnectedness. (Gouvea et al., 2017; UNECE 2015a; Fachinelli et al., 2023). Smart and

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sustainable cities (Höjer and Wangel, 2015; Lee et al., 2023) are an idea that integrates sustainable development, industrialization, and technological advancement. This concept blends urban development and liveable community; meanwhile, it concerns the use of ICT to help urban areas become more resilient and to improve the standard of living of residents (Akande et al., 2019; Al-Nasrawi et al., 2015; Fachinelli et al., 2023). The application of ICT in urban systems and realms encompasses, detecting, acquiring, recording, synchronizing, and data exchange for the aim of tracking and evaluating urban spaces to accomplish specific objectives (Bibri and Krogstie, 2017a).

In an increasingly urbanized world, smart urban sustainability is a key strategy for addressing the pressing challenges of urban development while striving for a better future in areas of smart environment and smart building concepts relationships (Apanaviciene et al., 2020; Toli and Murtagh, 2020). Smart urban sustainability according to Bibri and Krogstie (2017a) and Yigitcanlar et al. (2019) is a concept and approach that addresses the complex challenges posed by rapid urbanization and the need to create cities that are both environmentally friendly and socially inclusive. It involves the integration of technology, innovation, and sustainable practices to enhance the quality of life for urban residents while minimizing the negative impacts on the environment. Ensuring urban sustainability include leveraging the advantage of ICT technique to improve urban transportation systems (Lee et al., 2020); analyzing data on urban public safety (Fachinelli et al., 2023; Cai et al., 2023); fostering sustainability, resilience, and energy efficiency (Bifulco et al., 2016; Zeng et al., 2022); disaster preparedness and real-time data on weather pattern (Bartoli et al., 2015). In terms of transportation, ICT would help in providing real-time traffic updates and enabling intelligent traffic management systems. Also, this would reduce congestion, improve air quality, make transportation more efficient, and improve smart growth. A pivotal role in enhancing public safety within smart cities, encompassing real-time monitoring of crime hotspots, intelligent surveillance systems, and emergency response systems. Smart grid systems optimize energy usage in buildings, monitor power consumption patterns, and promote clean energy sources. Through these measures, smart cities curtail greenhouse gas emissions, conserve resources, and champion environmental sustainability.

In connection with smart urban sustainability, stakeholders play a critical role in the development, implementation, and management of smart city initiatives. Stakeholders, comprising a diverse group of individuals, organizations, and entities, play a pivotal role in the sustainability of smart city initiatives (Fernandez-Anez, 2016; Jayasena et al., 2021). Their involvement is not only desirable but also indispensable for the successful development, implementation, and ongoing management of these initiatives (Nama and Pardo, 2011; Bifulco et al., 2016). Notably, stakeholders bring unique perspectives, and expertise, thus contributing to the overall sustainability and effectiveness of smart city strategies. Collaboration with stakeholders ensures that smart city strategies are well-informed, inclusive, adaptable, and aligned with the diverse interests and needs of urban communities (Paskaleva et al., 2017). By actively involving stakeholders, a more resilient, innovative, and sustainable urban development could be achieved.

The primary focus of 21st-century smart cities remains parts of urban sustainability. African nations' rising urbanization needs a greater connection between the individual and changing and developing (Cohen, 2006; Awumbila, 2017). Lagos city in Nigeria is currently expanding in population and the government is focusing on implementing a slew of smart city projects aiming at enhancing the lives of its residents and promoting sustainable development. The country's government and stakeholders are working on the Lagos smart urban initiative, which intends to substantially transform the city's technology infrastructure and promote economic development (Agunbiade et al., 2021). In view of this development, and despite the possible advantages of ICT in enhancing a smart urban environment, much remains unknown about how to optimally harness ICT to achieve the impacts by the stakeholders in Nigeria context (Höjer and Wangel 2015; Slavova and Okwechime, 2016; Bibri and Krogstie, 2017b). Consequent to the drives to transform the Lagos urban systems, additional empirical research on the role of ICT in urban sustainability needed to be explored. This research seeks to bridge the knowledge gap regarding how ICT can be optimally harnessed to realize the intended impacts on sustainability as envisioned by stakeholders within the Nigerian urban environment.

The major research aim of this study is to investigate the role of Information and Communication Technology (ICT) in advancing urban sustainability in the context of Lagos, Nigeria, amidst the city's rapid population growth and the implementation of smart city projects. This study's research objective includes the following: i). to assess the extent to which ICT contributes to consolidating smart urban development in Nigeria, with a focus on its significance in the overall urban development landscape; ii). to unravel the intricate relationship between ICT, stakeholder involvement, and urban development, elucidating how ICT fosters or hinders sustainable urban progress; iii). to explore the dynamics of stakeholder engagement and participation within the context of smart urban sustainability and how ICT influences these interactions.

The findings will have a theory and practical implications for policymakers and other stakeholders who are tasked with developing and implementing smart environment drive initiatives in Nigeria and beyond. This will help in identifying the most effective ICT solutions and strategies for achieving sustainable goals (Anthopoulos and Tougountzoglou, 2012; Lee et al., 2023). This study contributes to the scientific understanding of ICT's role in smart urban development in developing nations and provides innovative insights on inclusive and sustainable smart city strategies. In the subsequent section, we evaluated some relevant literature on Information and Communication Technology (ICT), smart urban environments, and stakeholders' involvement and engagement in smart city initiatives. The study discusses the important variables in the study framework and comes up with research hypotheses. The method adopted, as well as the outcomes of the statistical analysis, was equally presented. Lastly, the findings, conclusions, implications, as well as potential study limitations that influence future research, were documented.

2. Review of literature

2.1. Characteristics of a smart urban sustainability

Smart urban sustainability embraced a computerized configuration that concentrated on technology via the smart city and buildings (Ishida and Isbister, 2000). Recently, attention has shifted to increasingly complicated technologies that are supported by internet infrastructure and intellectual capabilities that are determining the city's expansion (Grossi and Pianezzi, 2017). Digitalization seems to be a novel arrangement of cities' settings founded on an array of interconnected qualities that enhance the standard of living of its people. The required comfortability index that would make living in the cities worthwhile is the major target of the smart city (Alfano et al., 2014; Grossi and Pianezzi, 2017). ICTs are now widely used in city government and management, where they are employed as resources and tools to enhance livability and achieve environmental sustainability (Anthopoulos and Tougountzoglou, 2012). It is evident that ICT represents the infrastructures and new technologies that form smart growth for city area administration and management as conceptualized by Feldman and Audretsch (1999), Bifulco et al. (2016), and Anttiroiko (2013). Smart city development encompasses indicators such as smart economy, smart people, smart governance, smart mobility, smart environments, and smart mobility, web-based technologies. Smart cities and buildings share many characteristics, as both are based on the integration of technology and data analytics to improve efficiency, sustainability, and quality of life (Lee et al., 2023; Agboola et al., 2023). A summary of the essential features of smart cities and smart buildings is presented in Table 1.

Table 1
Some of the essential features of smart cities and smart buildings.

	Domain	Summary of Features	Refs.
1.0	Connectivity	Smart cities and smart buildings rely on advanced communication networks to connect devices, sensors, and systems, enabling real-time monitoring, analysis, and control.	Ahvenniemi et al. (2017).
2.0	Data-driven	Smart cities and smart buildings rely on data analytics to optimize energy consumption, reduce waste, and improve operations. This requires the use of sensors and other monitoring devices to collect data and advanced analytics tools to analyze and interpret the data.	Kaluarachchi (2022).
3.0	Automation	Smart cities and smart buildings use automation to improve efficiency and reduce human error. This can include automated lighting, HVAC systems, and security systems, among other things.	Bajer (2018); Merabet et al., 2021).
4.0	Sustainability	Smart cities and smart buildings prioritize sustainability by using renewable energy sources, optimizing energy consumption, reducing waste, and promoting environmentally friendly practices.	Anthopoulos and Tougountzoglou (2012).
5.0	User-centered	Smart cities and smart buildings are designed with the needs and preferences of their users in mind. This means user comfort and safety are prioritized.	(Grossi and Pianezzi, 2017).
6.0	Interoperability	Smart cities and smart buildings are designed to be interoperable, meaning that they can communicate and exchange data with other systems and devices, both within their ecosystem and with external systems.	(Antonios et al., 2023).
7.0	Adaptability	Smart cities and smart buildings are designed to be adaptable and scalable so that they can be easily upgraded and expanded as technology evolves and user needs change.	(Mehmood, 2016; Fuenfschilling et al. 2019).

2.2. Stakeholders' involvements and engagements in the smart city initiatives

Smart city initiatives and executions involve a wide range of stakeholders, including government agencies, private sector enterprises, and community organizations, among others. Many scholars have studied stakeholders' involvement in the smart city (Schmidt, et al., 2020; Rendon et al., 2021; Anthony, 2023; Del-Real et al., 2023). The research works focus on examining the viewpoints of techno-stakeholders in the context of smart cities. The studies' results revealed that data-driven initiatives have the potential to shape the perspectives of techno-stakeholders when it comes to the development of smart cities. Findings also revealed that stakeholders' involvement and participation are instrumental in driving urban sustainability. Also, stakeholders' diverse perspectives, local knowledge, and commitment contribute to the development and implementation of effective sustainability strategies, policies, and projects. Engaging stakeholders fosters a sense of ownership, encourages innovation, and ultimately leads to more sustainable and resilient urban communities.

Part of the benefits of stakeholder engagement in smart cities' governance is the ability to promote social justice engagement through innovation and creativity (Viale et al., 2017; Anthony, 2023). By involving residents in the smart city formation and execution, the utmost success of smart city initiatives could be achieved. Promoting stakeholder engagement is also vital for ensuring the sustainability and scalability of smart city initiatives. By involving private sector companies and other organizations in the planning and implementation of smart city initiatives, stakeholders can leverage their expertise and resources to help ensure that initiatives are financially viable. This can help to ensure the success and sustainability of smart city initiatives and to promote economic growth and development. Table 2 presents the summary of reviews of stakeholders' involvement in smart city development.

However, stakeholder engagement in smart cities can also present challenges. For example, stakeholders may have competing interests and priorities, which can make it difficult to reach a consensus on key issues. In addition, stakeholders may have different levels of expertise and knowledge about smart city initiatives, which can make it difficult to ensure that all stakeholders have an equal say in the planning and implementation process (Rendon et al., 2021; Del-Real et al., 2023; Agboola et. al., 2023). To address these challenges, smart cities must adopt a proactive and participatory approach to engage stakeholders. This involves regular communication and transparent decision-making processes. Additionally, fostering partnerships and collaborations, including public-private ventures, should be a priority. In such contexts, smart city initiatives may need to address these foundational issues before delving into advanced technological solutions. Ensuring inclusivity and accessibility for all residents is paramount. In developing nations, disparities in technology access and digital literacy can hinder the effectiveness of smart city solutions. Consequently, bridging these gaps necessitates investment in digital infrastructure and providing residents with adequate training and support to utilize smart city technologies effectively.

2.3. Adaptability in smart urban environment

Adaptability in the urban refers to a city's capacity to adjust and respond to changing circumstances, challenges, and opportunities. It involves the flexibility to adapt policies, infrastructures, and systems to meet evolving needs and address emerging issues (Mehmood, 2016; Fuenfschilling et al., 2019). Adaptability incorporates smart buildings and a resilient built environment. Adaptability is a key feature of smart buildings that can help these structures remain relevant and effective over time. Smart buildings use advanced technology to monitor, regulate, and optimize their many systems and functions, such as lighting, HVAC, and security (Bajer, 2018; Merabet et al., 2021). The goal is to improve the overall performance of the building, increase occupant comfort, and save running costs. Smart buildings can demonstrate adaptability through, flexibility in design (Lee et al., 2023; Agboola et al., 2023c). This shows that smart buildings could be designed to accommodate future changes in technology and usage patterns. Secondly, modular construction techniques make it easier to add or remove building components as per changing needs. The third is interoperability. Smart building systems should be interoperable, meaning they can integrate with other systems and devices, making it easier to upgrade or change individual components. Fourthly, is data-driven decision-making. Smart buildings should leverage data to make informed decisions about building systems and usage patterns, allowing for better optimization and efficiency. It is crucial to understand that choosing a smart building can offer several advantages, such as reduced expenses, time savings, and fostering a stronger sense of comfort and resilience (Zeng et al., 2022).

Table 2
Reviews of stakeholders' involvement in smart cities development.

	Domain	Summary of Features	Refs.
1.0	Mutual Dependence	Smart Cities development relies on the active involvement of various stakeholders, including government bodies, private sector entities, citizens, and non-governmental organizations. These stakeholders contribute resources, expertise, and innovation to support the development and sustainability of Smart Cities.	Faraji et al. (2019); Angelidou (2017); Rendon et al. (2021).
2.0	Responsive Governance	Stakeholders play a pivotal role in reshaping the interactive system to ensure inclusivity. Consequently, governance in smart cities is connected to leadership models that encourage the integration of cultures to foster interaction and collaboration.	Nuzir and Saifuddin (2015); Woolley (2010); Del-Real et al. (2023).
3.0	Innovation Catalyst & Social Inclusion	Stakeholders, particularly the private sector and research institutions, drive innovation within Smart Cities.	Viale et. al. (2017); Anthony (2023)
4.0	Resource Allocation	Stakeholders, including public and private investors, allocate financial resources to fund smart city initiatives. Their financial commitment is essential for the implementation of large-scale projects that improve infrastructure, transportation, and sustainability.	Wu and Raghupathi (2018); Freudendal-Pedersen et al. (2019).
5.0	Environmental Sustainability	Environmental organizations and advocacy groups are key stakeholders in Smart Cities, advocating for sustainable practices and pushing for eco-friendly urban planning.	Schmidt et al. (2020); Gouvea et al. (2017); and Wu and Raghupathi (2018).
6.0	Data and Privacy Management	Stakeholders are central to addressing data privacy and security concerns associated with Smart Cities. They work together to establish regulations and safeguards to protect citizens' data.	Moglia et al. (2018); Kaluarachchi (2022); and Agboola et al. (2023c).
7.0	Community Engagement	Through the resolution of obstacles obstructing social justice, stakeholders can implement reforms aimed at facilitating the involvement of diverse groups in addressing the developmental requirements of smart cities.	Puron-Cid, (2015) and Anthony (2023).

3. Methods

3.1. Measurement of variables

This study's conceptual framework is hinged on the previous kinds of literature which also help in selecting appropriate indicators for analysis. Measuring the ICTs comprises interconnected modules, namely: the application of the Internet of Things (IoT), big data analytics, digital divide; and Artificial Intelligence (AI) in a broader spectrum (Ahvenniemi et al., 2017; Akande et al., 2019). As a result, numerous smart city assessment frameworks that place a heavy emphasis on ICT and urban sustainability may be developed. Therefore, the study utilized a model that has been employed as a rating system as produced through six (6) items, namely smart mobility, smart environment, smart living, smart people, smart economy, and smart governance, for urban sustainability (Akande et al., 2019; Giffinger et al., 2007; Bifulco et al., 2016).

ICTs enable the integration of stakeholders into decision-making processes, enhance transparency, and encourage public involvement in urban development policies. Through ICT platforms, stakeholders can access information, provide feedback, and participate in the co-creation of sustainable urban solutions. Open data efforts, crowd-sourcing, and co-creation platforms are examples of how stakeholders can participate in smart cities (Poplin, 2014; Lalicic and Önder, 2018). Hence, five (5) items were used to measure the stakeholder's involvement and participation in smart urban development using pieces of literature from Lalicic and Önder (2018), Gordon et al. (2011) and Simonofski et al. (2021). Open modern digital media technologies could assist in attaining agreement among different stakeholders.

Smart urban sustainability is a holistic approach to urban development that leverages technology and innovative solutions to create environmentally friendly, efficient, and livable cities. This study used six (6) items to measure smart urban sustainability based on the previous studies. It encompasses various facets, including intelligent transportation, eco-friendly practices, improved quality of life, community engagement, economic growth, and effective Governance (Mehmood, 2016; Majeed, 2018; Zeng et al., 2022; Lee et al., 2023). By integrating smart technology and sustainable practices, smart urban sustainability could enhance urban living while minimizing environmental impact, making cities more resilient and prosperous for present and future generations. Adaptability and resilience play a vital role in ensuring cities effectively respond to environmental, social, and economic changes while minimizing negative impacts. By adopting adaptability in the urban study, the quality of life for residents could be enhanced (Simonofski et al., 2021, Lee et al., 2023; Zeng et al., 2022). This study measured adaptability and resilience with two (2) major items as suggested by previous studies. Resilience refers to the ability to bounce back, adapt, and thrive in the face of challenges. Resilience complements adaptability by focusing on a city's capacity to absorb and recover from shocks, stresses, and disruptions. It encompasses physical, social, economic, and environmental dimensions, all of which contribute to urban sustainability (Mehmood, 2016; Zeng et al., 2022).

Summarily, Table 3 shows the constructs scales and questionnaires' variables measurement. A closed-ended questionnaire tailored to address the predefined research objectives was employed to gather insights from the participants. Drawing from the variables identified in the reviewed literature, the questionnaire was structured into three distinct sections. The first section focused on gathering information about the participants' backgrounds. This measure was deemed vital to ensure that respondents met the study's requirements and also functioned as a precautionary measure to enable the researcher to collect supplementary data, consequently mitigating potential respondent biases, as highlighted by Hektner et al. (2007). The second and third sections sought respondents' opinions on the ICTs, Stakeholders' involvement, and participation. The fourth section dwelt on Smart urban sustainability, adaptability, and resilience. A five-point Likert scale was utilized to assess the ranking of each indicator and its sub-indicators, consistent

Table 3
Constructs scales and source of the questionnaire.

Sections	Factors	No of Items	Scales	Source
1.	Demographic		Nominal & Ordinal	Researchers
2.	Information and Communication Technology (ICT)	5 Items	5-point Likert scale	Akande et al., 2019; Giffinger et al. (2007), and Bifulco et al. (2016
3.	Stakeholders' Involvements & Participation	5 Items	5-point Likert scale	Lalicic and Önder (2018), Gordon et al. (2011); Simonofski et al. (2021).
4.	Smart Urban Sustainability	6 Items	5-point Likert scale	Mehmood, 2016; Majeed, 2018; Zeng et al., 2022; Lee et al., 2023).
5.	Adaptability & Resilience	2 Items	5-point Likert scale	Yilmaz, 2021; Zeng et al., 2022

Measurement scale ranged from '1' (indicating strong disagreement) to '2' (representing disagreement), '3' (signifying neutrality), '4' (indicating agreement), and '5' (representing strong agreement).

with the approach employed in prior comparable studies. Based on previous research, the surveys were designed using five-point scales (Agboola et al., 2018; Solomon et al., 2015). Respondents were required to select one of five available choices corresponding to the following categories: "Strongly Disagree (1)," "Disagree, "2'; "Neutral, "3"; Agree, "4'; and "Strongly Agree (5)".

3.2. Conceptual framework and hypothesis developments

The enormous growth of ICT over the last decade, as well as its application in the push for a smart urban environment, has been critical in solving numerous urbanization concerns to citizen quality of life. Numerous scholars have developed modules from this framework and utilized them to investigate the relationship between ICT and sustainable development in various contexts (Azadnia and Zahedi, 2018; Cruz-Jesus et al. 2017). This study will explore whether Information and Communication Technology (ICT) will have a significant positive impact on urban sustainability. Sustainability assessment methodologies, on the other hand, recognize a positive linear relationship between ICT growth and environmental sustainability, as proposed by Gouvea et al. (2017) and Wu and Raghupathi (2018). The elements of urban development and sustainable can be viewed as a tactic to emphasize the expanding significance of ICT infrastructure in this context (Bekaroo et al., 2016; Gonel and Akinci, 2018). It is possible to guarantee that projects are responsive to the needs and concerns of the community by incorporating stakeholders in the planning and implementation process. This can help to build support for the initiatives to secure their long-term viability. When there are many correlations among multiple variables and the data are non-normally distributed, the SmartPLS technique can be used to do explanatory research (Hair et al., 2014; Chaudhuri, 2012). To investigate the unique implications of information and communication technology on urban sustainability, and stakeholders' involvements cum participations, a SmartPLS comprising dependent, independent, and control variables (H4) was constructed. Fig. 1 depicts the conceptual framework.

3.2.1. Hypothesis (H1): Will ICTs have a significant positive influence on stakeholders' involvement and participation in Smart Urban sustainability?

Open data is information that is publicly accessible and usable by anybody and is made available by the government. The goal of open data initiatives is to encourage individuals to participate in the planning phase of improving their community by co-creating innovative online services produced by inhabitants to improve inhabitants' standard of living (Porter et al., 2018). Furthermore, ICT-enhanced resident experiences could provide new avenues for encouraging people to take an active part in and learn about their surroundings. Safeguarding personal information and preventing data breaches is paramount to ensure public trust and confidence in ICT-enabled urban systems. Additionally, the digital divide poses a significant challenge to equitable access to ICT and smart city services. Bridging this divide requires efforts to provide affordable and accessible digital infrastructure, promote digital literacy, and ensure inclusivity in technology adoption.

To fully harness the influence of ICT on urban sustainability, it is

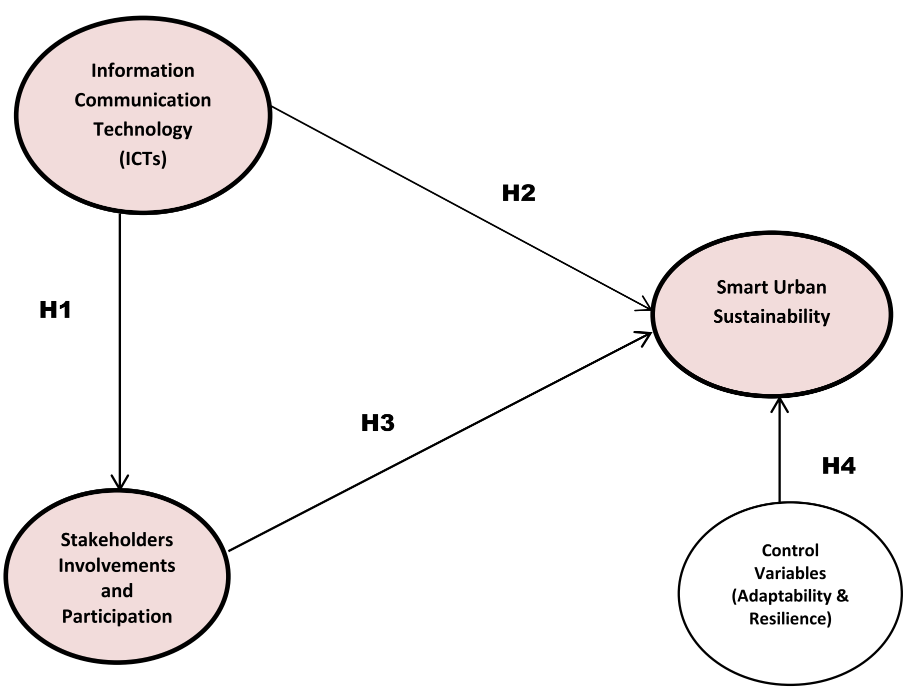

Fig. 1. Proposed hypothetical model. source: author's conceptualization.

crucial to adopt a comprehensive and holistic approach (Mehmood, 2016; Zeng et al., 2022). This entails collaborating with stakeholders from diverse backgrounds, including government agencies, private sector organizations, community groups, and academia. By fostering collaboration, knowledge sharing, and interdisciplinary partnerships, cities can develop inclusive, equitable, and sustainable smart city strategies. ICT also plays a crucial role in enhancing livability and quality of life, energy conservation, and creating healthier living environments (Simonofski et al., 2021).

3.2.2. Hypothesis (H2): Will ICTs have a significant positive influence on the achievement of smart urban sustainability?

In today's modern city, scientific creativity and its ICT implementations are regarded as absolutely crucial for bringing more advanced remedies to social, economic, and environmental challenges and for rolling out new services to inhabitants (Bibri, 2015b). The impact of information and communication technology (ICT) on smart urban sustainability needs to be explored. ICT could be viewed as a solution for strengthening the protection of the environment, alleviating the negative effects of human actions on the environment, and tackling significant environmental concerns such as global warming and sustainability (Majeed, 2018). ICT could be explored to know if it could assist in averting environmental destruction by raising consciousness about environmental problems and promoting the use of technology that is good for the environment (Plepys, 2002; Lashkarizadeh and Salatin, 2012, Majeed, 2018). Its applications could aid in the prediction and management of environmental risks. Moreover, huge urban alterations are being predicted with the arrival of ICT in the next phase of computing.

The influence of Information-Communication Technology (ICT) on urban sustainability is a cogent and significant aspect of modern urban development. ICT has the potential to transform cities and enhance their sustainability in numerous ways. By leveraging digital technologies, data analytics, and smart systems, ICT can optimize resource management, improve energy efficiency, enhance transportation networks, and foster environmental conservation. One of the primary influences of ICT on urban sustainability is its ability to facilitate the monitoring and management of critical urban infrastructure systems (Lee et al., 2023; Zeng et al., 2022). Through real-time data collection and analysis, ICT enables the efficient monitoring of energy and water consumption, waste management processes, and transportation networks. This allows for proactive decision-making, resource optimization, and reduction of environmental impact.

3.2.3. Hypothesis (H3): will stakeholder involvement and participation have a significant positive influence on achieving Smart urban sustainability?

Stakeholder involvement and participation need to be considered in achieving urban sustainability. Achieving urban sustainability requires a holistic and integrated approach that involves various stakeholders, including residents, businesses, non-profit organizations, and government agencies. According to Del-Real et al. (2023), and Randolph and Bauer (1999); the involvement and participation of stakeholders in urban sustainability initiatives could be in several ways. First, stakeholders bring a range of perspectives, expertise, and resources to the table, which can help to identify innovative and effective solutions to complex urban sustainability challenges. By involving a diverse group of stakeholders, it is possible to tap into a wide range of knowledge and skills, which can lead to more effective and sustainable outcomes. Second, stakeholder involvement and participation can help to build a sense of ownership and commitment among residents and other stakeholders. Third, stakeholder involvement and participation can help to increase transparency and accountability in urban sustainability initiatives. When stakeholders are involved in the decision-making process, they can hold government agencies and other organizations accountable for their actions and ensure that the initiatives are being implemented equitably and transparently. This can help to build trust between different stakeholders and create a more collaborative and effective approach to achieving urban sustainability. Fourth, stakeholder involvement and participation can help to ensure that urban sustainability initiatives are in line with the community's requirements and goals.

3.2.4. Hypothesis (H4): Will the control variables of urban adaptability and resilience impact smart urban sustainability?

Smart urban sustainability refers to the communities' ability to address their citizens' demands in a manner that guarantees the well-being of future generations as well. The hypothesis will explore whether urban adaptability and resilience will reduce the associated challenges of urban sustainability (Yilmaz, 2021; Agboola et al., 2023a, 2023c). Urban adaptability and resilience play crucial roles in shaping urban sustainability. As cities face increasing challenges and uncertainties, such as climate change, population growth, and resource constraints, their ability to adapt and withstand shocks becomes paramount.

The concepts of urban adaptability and resilience encompass various dimensions that contribute to sustainable urban development (Fuenfschilling, et al., 2019; Agboola et al., 2023). It involves fostering social inclusivity and empowering communities. By promoting inclusiveness, cities can engage diverse stakeholders, facilitate participatory decision-making, and ensure that the needs and voices of marginalized groups are considered in urban development processes. This inclusivity strengthens social cohesion, enhances resilience, and supports sustainable urban growth. From a physical perspective, resilient cities prioritize the development of robust infrastructure that can withstand natural disasters, extreme weather events, and other hazards. This includes designing buildings and infrastructure to be more resistant to climate impacts, enhancing water management systems, and implementing effective emergency response plans.

3.3. Data gathering and analysis

The quantitative study methodology was chosen due to its robustness and suitability for examining the objectives of the study in areas of smart urban development and ICTs. Quantitative research is well-suited for this research topic because of its emphasis on objective data collection, statistical analysis, and generalizability (Creswell and Creswell, 2017). Furthermore, quantitative research allows for the collection of numerical data, offering precise and quantifiable insights into the variables being studied, as substantiated by previous research (Anthony, 2023; Kaluarachchi, 2022). These scholars have successfully used this approach to establish connections among various variables in scientific or quasi-data-gathering instruments. Consequently, the quantitative research approach provides evidence-based insights for informed decision-making and the advancement of sustainable urban development.

Respondents were chosen from a pool of experts located in the South West of Nigeria who are knowledgeable in the smart environment. This group encompassed professionals such as consultants, site supervisors, city planners, designers, computer specialists, and software engineers within the ICT and construction industry. These are professional stakeholders working in government agencies, the private sector, and non-governmental organizations, among others, with diverse interests. Thus, effective communication, collaboration, and engagement among them are essential for the successful planning and implementation of smart city initiatives. Due to the absence of a comprehensive database for the lists of professionals, the snowball sampling method was employed to connect with potential respondents. Snowball sampling allows inclusivity and diversity by encouraging respondents to recommend others, thereby broadening the range of participants as supported by the previous study by Dusek et al. (2015). This approach allowed for a more flexible means of reaching respondents, diminishing the influence of inherent biases often associated with other sampling techniques

(Snijders, 1992).

The data collection process involved the distribution of surveys through online platforms and traditional mail, utilizing a drop-and-pick approach. The survey distributions were conducted in the research areas; between April and August of 2021. The analysis was carried out using univariate regression tools of Structural Equation Modeling of Partial Least Squares (SmartPLS 3.0 Edition). The tool is a fundamental statistical technique renowned for its capabilities in data analysis and statistical modeling. Also, it is a powerful software tool widely utilized to explore relationships between variables, make predictions, and derive meaningful insights from data. This tool enables users to model the connection between a dependent variable and one or more independent variables (Sarstedt and Cheah, 2019). Additionally, it facilitates the assessment of the strength and direction of these relationships, the evaluation of predictor significance, and the formulation of predictions based on the model.

4. Results

4.1. Demographic of respondents

To eliminate bias analysis and dispute, this empirical research strategy was deemed appropriate (Creswell and Creswell, 2017). Certain ICT variables were applied to employ principal component analysis (PCA), a univariate regression model. The SmartPLS is frequently employed to investigate particular impacts between numerous variables in a smaller dataset (Sarstedt and Cheah, 2019). These approaches are employed to provide comprehensive responses to the research inquiries and to serve as a reference for other scholars studying ICT-related topics. A sample size of one hundred or above was deemed adequate for variance-based structural equation modeling (Hair et al., 2012). A total number of 725 survey questionnaires were distributed via online and traditional one-on-one distribution methods. Meanwhile, 518 completed surveys were retrieved amounting to 71.44 % response rates. The data were screened and a total number of 17 invalid responses were recorded on the collated questionnaires, while 26 outliers and 23 missing data incidents were also registered. Therefore to eliminate bias in the fit outcome of this analysis, approximately 66 data sets were excluded. Overall, suitable data sets of 452 were eventually analyzed. The sample was found adequate at a value (of 0.846); while the Normality tests demonstrated the statistical model dataset. Skewness and kurtosis values are used to construct the normal distribution, and collection (Hair et al., 2012). Skewness and kurtosis Z values should be higher than 1.96, and the Shapiro-Wilk estimate p-value should be higher than values of 0.05. Yet, data have never been meant to be fully authentic; 80 percent of the skewed z-values are more than the values of 1.96, which was enough to justify further examination. (Agboola et al., 2018; Hair, 2012). In addition, 31 outliers were found and eliminated.

Table 4 presents the detailed results of the respondents' demographics. The gender of the sample was 54.42 % of males and 45.57 % of females. In terms of age, those respondents with age 18-35 years amounted to 24.11 %, the 36–45 years of respondents having 36.06 %, while the respondent's age of 46 years and above gave 39.82 %. Respondent's education level indicated that 33.62 % had a Primary certificate, 32.30 % possessed a Bachelor's Degree or HND certificate, and about 22.56 % had Master's Degree / Ph.D. certificates. The results of the study on "Stakeholders' Involvement Awareness in Smart Cities Development" indicate that 91.81 % of respondents acknowledged having awareness of stakeholder involvement, while only 8.18 % stated that they were not aware. In simpler terms, the majority of the participants were aware of the importance of involving stakeholders in the development of smart cities, but a small percentage of them were not aware. This suggests that there is a significant level of awareness among the surveyed individuals regarding the role of stakeholders in smart city development. The survey results reveal a diverse representation of professionals involved in the context of smart city development. Among

Table 4
Respondents-demographics (N=452).

Factors	Categorization	Frequency	Percentage (%)
Gender	Male	246	54.42
	Female	206	45.57
Age	18–35	109	24.11
	36–45	163	36.06
	46– above	180	39.82
Marital Status	Married	303	67.03
	Single	149	32.96
Certification	Primary	198	33.62
	Bachelor's Degree (BSc/HND)	152	32.30
	Master's Degree/ Doctoral Degree	102	22.56
Professional Background	Consultants/ designers	108	23.89
	Site supervisors	137	30.30
	City planners	88	19.46
	Software engineers	40	8.84
	Structure Engineers / Computer specialists	79	17.47
Awareness of Stakeholders' Involvement in Smart cities Development	Yes	415	91.81
	No	37	08.18
Stakeholders' affiliations	Government agencies	98	21.68
	Private sector	73	16.15
	Community organizations.	80	17.69
	Academic and Research Institutions	135	29.86
	Non-Governmental Organizations (NGOs)	66	14.60

the respondents, site supervisors constitute the largest group, making up 30.30 % of the participants. Site supervisors play a critical role in overseeing the practical aspects of construction and development projects within a smart city, ensuring that plans are executed effectively on the ground.

In close succession are the consultants and designers, accounting for 23.89 % of the participants. These individuals are pivotal in the early stages of smart city planning, offering expertise in design, architecture, and the overall vision of the urban development projects. Their role is instrumental in shaping the conceptualization and aesthetics of smart cities. City planners, comprising 19.46 % of the respondents, occupy a central position in smart city development. They are responsible for urban planning, zoning, and land use regulations, which are essential components in creating sustainable and efficient urban environments. Meanwhile, software engineers, representing 8.84 % of the survey participants, bring crucial technological expertise to the table. Their role involves the development of software solutions and applications that underpin various smart city initiatives, from IoT systems to data analytics platforms.

Lastly, structure engineers and computer specialists constitute 17.47 % of the respondents, blending expertise in both structural engineering and computer science. They play a dual role in ensuring the physical integrity of smart city infrastructure and supporting its digital and IT components. Together, these professionals contribute their unique skills and perspectives to the multifaceted endeavor of smart city development, reflecting the interdisciplinary nature of the field and the need for collaboration across various domains to create successful and sustainable smart cities.

The examination established acceptable correlations between the constructs using varimax rotation. The Kaiser-Meyer coefficient was 0.846, and a 0.000 positive value was taken (Bartlett, 1954; Kaiser, 1974). The extraction approach was utilized in the major section, and after four iterations, the rotation converged; with an AVE of minimum values of 0.5 and reliability measures of minimum values of 0.70, all components were loaded in the predicted order (Hair et al., 2012), and significant p-values of 0.05; was bootstrapped to explain the partial minimal regression square (R^2) explanations of the model (Hair et al., 2012). In this investigation, the measurement model was tested. The controversies surrounding the usage of information and communication technology (ICTs), Urban Sustainability, stakeholder involvement and participation, and control variables (adaptability and resilience) were elicited.

4.2. Validity and reliability of constructs

To verify content validity, past studies' assessment scales were used, the majority of which had been based on previous evaluations and were slightly changed to meet this research setting. Following the changes, using five-point Likert-style scales, all of the items received positive feedback. Meanwhile, Information Communication and Technology (ICTs) were assessed using the five items proposed by Akande et al. (2019); Giffinger et al. (2007), and Bifulco et al. (2016), asked respondents to rate how much they agreed with certain statements, such as "*The use of the Internet of Things (IoT) is a good idea to enhance urban sustainability*"). As demonstrated in Table 5, the scale has achieved a high degree of consistency (Cronbach's = 0.953). The six items in the urban sustainability scale also provided a high level of consistency (α = 0.915); they were adapted from Bekaroo et al. (2016); and Gonel and Akinci (2018) with the degree of the respondent's level of agreement with the statement for example "*The degree of Urban smart mobility in urban sustainability is a good idea*"). To measure the stakeholder involvement and participation, we adopted five items (α = 0.928) adopted from Del-Real et al. (2023), and Randolph and Bauer (1999); with the respondents' level of agreement with the statement "*Stakeholders involvement brings innovative and effective solutions to the complex urban challenges*". The two control variables (α = 0 .901) include the adaptability and resilience of urban sustainability was adapted from Yilmaz (2021); and Agboola (2022; 2023a). Respondents' responses were sought on a statement such as '*Using adaptability will reduce the associated challenges of urban sustainability*'.

Because the study's model covers both formative and reflective components at the same time, SmartPLS is an effective methodology for testing the hypotheses (Chin, 1998). It does not make assumptions about the data's underlying distribution and therefore does not necessitate big sample numbers (Henseler et al., 2009). A confirmatory factor analysis is to ensure the reliability and validity of the constructs. A model's reliability test was carried out considering Cronbach's alpha values. The values range between 0.901 and 0.953, which confirms the model's reliability for subsequent analysis. Cronbach alpha values greater than 0.700 are acceptable based on minimum standards suggested by Götz et al. (2009). The initial factor loadings revealed item loadings with constructing scores of around 0.9, much above the acceptable standard of 0.7. (Henseler et al., 2009). Second, all reflective constructions' composite reliabilities were greater than 0.9, indicating their internal consistency. Third, in support of convergent validity, the Average Variance Extracted (AVE) values for all reflective constructs are greater than 0.8, which is higher than the benchmark of 0.5. (Fornell and Larcker, 1981). Fourth, we assessed if the square root of the AVE was higher than the common variance across constructs (correlations) to confirm the discriminant validity of the reflective constructs, as proposed by Fornell and Larcker (1981). This criterion was met by all pairs of constructs, lending credence to the discriminant validity of measures (see Table 6).

Before cross-validation, using confirmatory factor analysis, exploratory factor (EF) analysis can lead to a helpful model-specific algorithmic technique. Exploratory factor analyses (EFA) are approaching in which the data are studied and descriptions of the many parameters required reflecting the data presented are provided. EFA variables were related to the latent construct, whereas CFA is indicators anticipated for the outcomes. CFA is critical in the assessment means of validating or

Table 5
The measurement constructs showing the standard loadings.

Constructs / Variables	Items Codes	Standard loadings	Cronbach's Alpha	Extracted-average variance
Information Communication Technology (ICT)			**0.953**	**0.83**
1. The use of the Internet of Things (IoT) is a good idea to enhance urban sustainability	ICT1	0.821		
2. The use of Cloud Computing is a good idea to enhance urban sustainability	ICT2	0.803		
3. The use of Big data Analysis is a good idea to enhance urban sustainability	ICT3	0.712		
4. The use of the Digital Divide is a good idea to enhance urban sustainability	ICT4	0.850		
5. The use of Artificial Intelligence (AI) is a good idea to enhance urban sustainability	ICT5	0.711		
Stakeholders' Involvement and Participation (STAIP)	**Items Codes**		**0.935**	**0.75**
1. Stakeholder involvement brings innovative and effective solutions to the complex urban challenges	STAIP 1	0.719		
2. Stakeholders' involvement brings a sense of ownership and commitments	STAIP 2	0.756		
3. Stakeholders' involvement increases transparency and accountability in urban sustainable initiatives	STAIP 3	0.819		
4. Stakeholders' involvement ensures alignment of urban sustainability initiatives with the needs and priorities of the community	STAIP 4	0.701		
5. Stakeholders' involvement allows active participation and implementation in urban development initiatives plans and strategies	STAIP 5	0.800		
Smart Urban Sustainability (SURBS)	Items **Codes**		**0.915**	**0.89**
1. The degree of Urban smart mobility in urban sustainability is a good idea	SURBS 1	0.778		
2. The degree of the smart environment in urban sustainability is a good idea	SURBS 2	0.786		
3. The degree of smart living in urban sustainability is a good idea	SURBS 3	0.716		
4. The degree of smart people's involvement	SURBS 4	0.771		

(*continued on next page*)

Table 5 (*continued*)

Constructs / Variables	Items Codes	Standard loadings	Cronbach's Alpha	Extracted-average variance
in urban sustainability is a good idea				
5. The degree of smart economy in urban sustainability is a good idea	SURBS 5	0.820		
6. The degree of smart government in urban sustainability is a good idea	SURBS 6	0.788		
Control Variables	**Items Codes**		**0.901**	**0.81**
1. Using Urban Adaptability will reduce the associated challenges of urban sustainability	CONTV 1	0.759		
2. Urban Resilience will reduce the associated challenges of urban sustainability	CONTV 2	0.780		

Table 6
Reflective construct dependability, as well as convergent and discriminant validity.

	CR	AVE	1	2	3	4	5
1. Information Communication Technology (ICT).	.942	.846	**.973**[a]				
2. Smart Urban Sustainability (SURBS)	.947	.834	.791	**.989**			
3. Stakeholders' Involvement and Participation (STAIP)	.951	.866	.671	.528	**.942**		
4. Urban Adaptability	.911	.805	.655	.318	.679	**.901**	
5. Urban resilience	.932	.892	.607	.794	.396	.742	**.976**

Notes: CR = composite reliability, AVE = average variance extracted.
Diagonal elements (bold figures) are the square root of the AVE (variance shared between reflective constructs and their measures).

rejecting a hypothesis (Gerbing and Hamilton, 1996; Hair et al., 2012). It presents the validity of the instrument as an exploratory study utilizing an exploratory factor analysis approach, and the primary conclusions about the techniques employed are acceptable. After bootstrapping, Table 7 compares the path coefficients to related variables (standardized deviation, sample means, t-report, and p-values). Furthermore, both the Bootstrapping and PLS Algorithms were reported, and the final computed values of the structured model are given in Fig. 2, together with the R-squares and model direction coefficients obtained.

4.3. Model results

After validating the measures, we used PLS with the required bootstrap of 500 iterations to estimate the effects proposed in the model and their significance (Chin, 1998). The proposed model's results (Fig. 2) demonstrated that Information and Communication Technologies (ICTs) positively impacted Urban Sustainability (β = 0.614, R^2 =0.85 of analyzed dimension), and stakeholders' involvement and participation (β = 0.572, R^2 =0.85 of analyzed dimension) in support of H1 and H2 respectively. Similarly, stakeholder involvement and participation will positively impact smart urban sustainability (β = 0.723, R^2 =0.58 of analyzed dimension), in which the H3 was also supported. Hypothesis H4 showing that the control variable of urban adaptability and resilience will positively impact smart urban sustainability (β =0.365, R^2 =0.43 of analyzed dimension) is equally confirmed. Meanwhile, all identified paths supported the $p < .05$ indications (Hair et al., 2012). Finally, the PLS algorithm demonstrated an 85 percent variance in the complete organized model. This is a confirmation that the use of information and communication technology such as the Internet of Things (IoT); the use of cloud computing; the use of big data analysis; the use of digital divides; and the use of Artificial Intelligence (AI) are all contributory factors to enhancing urban sustainability.

Finally, a possible indirect effect of Information and Communication Technology (ICTs) on Smart Urban Sustainability, through stakeholder involvement and participation was explored to determine the confidence intervals as suggested by Williams and MacKinnon (2008). This was done In this scenario, a confidence interval was determined after a bootstrap analysis with 5000 subsamples. The path coefficients derived from the bootstrapping computation were multiplied first, and the 95 % confidence interval was computed by excluding extreme instances using a percentile calculation proposed by Williams and MacKinnon (2008). The outcomes as presented in Table 8, suggested that Information and Communication Technology (ICTs) had a significant and favorable indirect effect (estimated indirect effect = 0.068) on Smart Urban Sustainability through Stakeholder involvement and participation since the 95 % confidence interval did not contain zero (0.001; 0.068). The projected total effect of the same technique in Information and Communication Technology on Stakeholder involvement and participation (0.023) was also significant at the 95 % level (0.001; 0.023). The remainder of the research model's indirect impacts (e.g., Stakeholder involvement and participation in smart urban sustainability through Information and Communication Technology) were non-significant. Urban adaptability and resilience are critical factors influencing smart urban sustainability. By enhancing adaptability, cities can proactively address emerging challenges, embrace innovative solutions, and foster inclusivity. Through resilience, cities can withstand shocks, recover quickly, and create sustainable environments for their residents. By prioritizing urban adaptability and resilience, cities can ensure a more sustainable and resilient future for all.

Table 7
Path coefficients.

Paths Constructs	Original Samples	Samples' Mean	Standardized Deviation (SD)	T-values	Sig. value (p)	Test Results
H1. Information and Communication. Technology → Urban Sustainability	0.614	0.562	0.275	3.462	0.000**	Supported
H2. Information and Communication Technology → Stakeholders' Involvement and Participation	0.572	0.471	0.178	0.684	0.000**	Supported
H3.Stakeholders 'Involvement and Participation → Smart Urban Sustainability	0.723	0.738	0.101	4.668	0.000**	Supported
H4.Urban Adaptability and Resilience → Smart Urban Sustainability	0.365	0.512	0.125	0.263	0.000**	Supported

Note: $p < .05$.

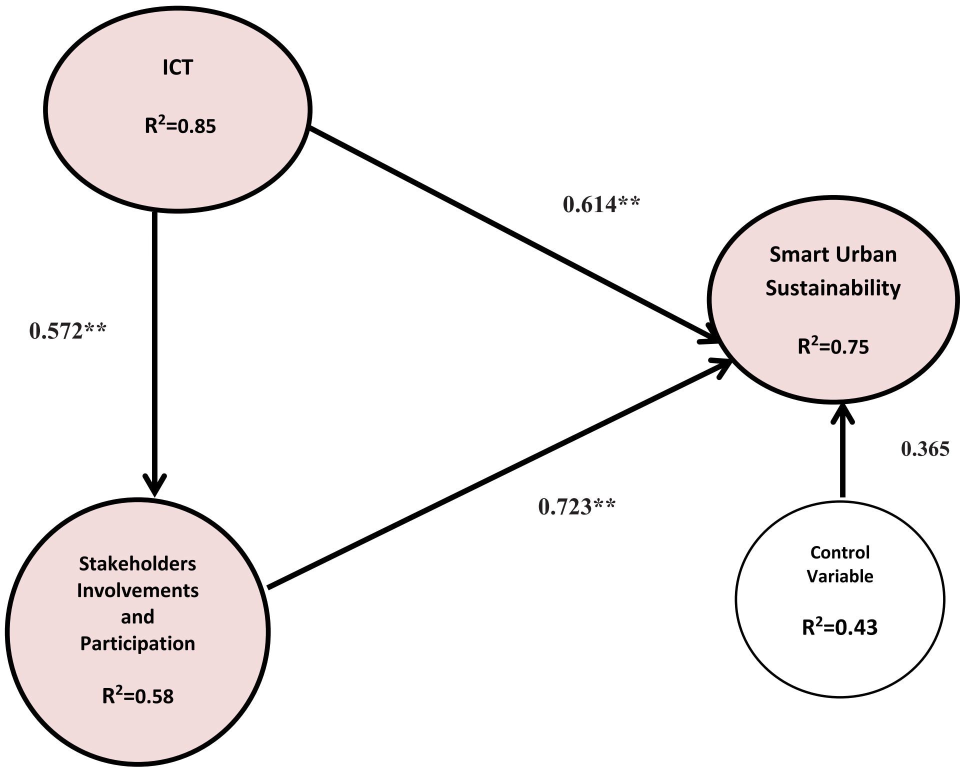

Fig. 2. Final structured model of the SmartPLS of ICT, Smart Urban Sustainability and Stakeholders' Involvements and Participation.

Table 8
Mediation analysis via bootstrapping.

Path	Indirect effect	Direct effect	Total effect
H1. Information and Communication Technology → Smart Urban Sustainability	**0.068**	0.001	0.068
H2. Information and Communication Tech. → Stakeholders' Involvement and Participation	**0.023**	0.001	0.023
H3.Stakeholders' Involvement and Participation → in Smart Urban Sustainability	**0.146**	0.515	0.661
H4.Urban Adaptability and Resilience → Smart Urban Sustainability	**0.138**	0.404	0.542

5. Discussion

The first objective aimed at assessing the extent to which ICT contributes to consolidating smart urban development in Nigeria, with a focus on its significance in the overall urban development landscape. Hence, this study's findings revealed that Information and Communication Technology (ICT) is positively associated with smart urban sustainability. This is consistent with the studies of Gouvea et al. (2017); and Wu and Raghupathi (2018). This further indicates that ICT can also improve communication and collaboration among stakeholders involved in urban sustainability initiatives. By providing platforms for sharing information and engaging with stakeholders, ICT can promote greater transparency and accountability in decision-making and increase community participation in sustainability initiatives as affirmed by the past works of Slavova and Okwechime (2016); Owojori and Okoro (2022); and Del-Real et al. (2023). Internet of Things (IoT) sensors, cloud computing, and big data analytics are examples of ICT tools that can be used to promote the development of a smart urban environment that incorporates smart projects.

IoT sensors, for example, can be used in smart cities and buildings to collect real-time data on air quality, energy consumption, and traffic flow, which are frequently utilized to enhance urban planning and resource allocation. These findings are in tandem with the findings of Zygiaris (2013) and Wu and Raghupathi (2018), who asserted that the planning agenda for urban innovation ecosystems begins with the city's willingness to execute smart policies and initiatives. It was further buttressed that urban areas should be designed on the specific components of the urban environment that invigorates the cities' smart sustainable future. Supporting this assertion were the studies by Gouvea et al. (2017) and Chen and Zhang (2019); who argued that urban areas are the most essential particles for a sustainable smart planet because they face global challenges at the local level. Consequently, upon this, the urban planning system should include new features that help the growth of a healthy, sustainable, and livable world, which was the central focus of the sustainable blueprint.

Further cloud computing could be used to store and process large amounts of data, while big data analytics will be beneficial to appropriate insights and patterns towards decision-making. To facilitate the use of ICT in smart cities and building development, several key strategies can be employed, such as creating open data platforms to share information and foster innovation, promoting public-private partnerships, and investing in digital infrastructure to ensure reliable and secure connectivity. These views are supported by the studies of Zygiaris (2013); Ahvenniemi et al. (2017; and Akande et al. (2019); as the authors agreed with the notion that the potential benefits of using ICT in urban development, which include increased efficiency, improved resource management, enhanced citizen engagement, and better quality of life for residents (Simonofski et al., 2021). The conceptual approach might potentially be used to coordinate and optimize municipal investments in green and broadband economies. It also offers smart city stakeholders a shared understanding of investment priorities. A vital preliminary planning stage is the examination of critical city resources that will contribute to the city's readiness for smart vision. The study's findings would help smart city planners avoid excessive expenses and leverage social and economic interconnections in the smart urban implementation plan.

However, there are also several challenges associated with ICT use, such as data privacy and security concerns, the need for new technical skills and expertise, and the potential for digital divides that exclude certain populations from accessing these technologies. The use of ICT is a critical component of urban development, and careful consideration must be given to both the opportunities and challenges associated with its use. Effective strategies and tools must be employed to ensure that these technologies are used in ways that promote equitable and sustainable urban development.

The second objective aimed to unravel the intricate relationship between ICT, stakeholder involvement, and urban development. It elucidates how ICT fosters sustainable urban progress. This study's findings indicated that ICT-based smart urban environments have the potential to significantly impact urban sustainability by enabling more efficient and effective use of resources, reducing carbon emissions, and enhancing disaster preparedness and response. For instance, smart grids and energy management systems can assist in lowering power consumption and boost the use of renewable energy sources, while smart energy systems can help minimize congestion problems; and improve air quality as concurred by the past studies of Al-Nasrawi and Irshaid (2020); and Park et al. (2021). This study revealed that smart city and building initiatives have the potential to significantly improve urban sustainability by enabling better management of resources, reducing environmental impacts, and enhancing the cities' strategies for development. Given this, the use of smart energy management systems can aid in the reduction of energy use and greenhouse gases, reducing waste and promoting circular economies. Information technology has traditionally been seen as a social advancement stimulant, as well as a significant factor in encouraging productivity expansion and urban development as substantiated by the past studies of Wang et. al. (2021); Lechman and Marszk (2019); and Stanley et al. (2018).

Similarly, smart initiatives contribute to attaining the Sustainable Development Goals of the United Nations (SDGs) by promoting sustainable urbanization and minimizing cities' ecological impact as concurred by studies by Chen and Hu (2020); Lee et al. (2020), and Udemba et al. (2022). It was reinstated that; leveraging ICT to optimize resource use, promote sustainable production, would help to achieve a number of the Millennium Development Goals, including SDG 7 about Affordable and Clean Energy, and SDG 9 in connection to infrastructure; and SDG 11 hinged on Sustainable Cities and Communities. These initiatives can contribute to achieving global sustainability goals such as reduced carbon emissions and improved resource efficiency by providing data-driven insights that can inform policymaking and resource allocation decisions. For example, Li (2022); and Khansari et al.,(2014); supported the notion that data on energy consumption and emissions can be used to identify areas of high impact and target interventions to reduce the negative impacts.

However, there are also potential trade-offs and unintended consequences associated with ICT-based smart initiatives. For example, ICT adoption could enhance power consumption and carbon emissions associated with the production, use, and disposal of electronic devices and infrastructure. For example, data usage may raise privacy and security concerns, and the implementation of new technologies may require significant investments and changes to existing infrastructure. Additionally, there may be concerns about the equitable distribution of benefits and impacts, as well as the potential for digital divides that exclude certain populations from accessing these technologies.

The third objective explores the dynamics of stakeholder engagement and participation within the context of smart urban sustainability and how ICT influences these interactions. In this vein, the findings reinstated a positive and significant influence of ICT on consolidating stakeholder involvement and participation as corroborated by past scholars such as Del-Real et al. (2023), and Randolph and Bauer (1999). The impact of ICT on stakeholders' involvement and participation in urban sustainability is transformative. It empowers individuals and groups to actively engage in the development of sustainable cities, fosters transparency and accountability, and drives innovation and efficiency in urban planning and development processes. By involving stakeholders' participation in the creation and execution of plans for sustainability initiatives, it is possible to tap into a range of knowledge and build a sense of ownership and commitment. It should be noted that the stakeholder knowledge and expertise could improve the use of ICT and thereby enhance urban sustainability. These stakeholders possess the potential to transform the way cities operate and thus contribute to a more meaningful sustainable future. The level of stakeholder (citizens, businesses, and government agencies) involvement and participation in urban sustainability initiatives and their influence on achieving urban sustainability in tandem with the previous studies, which include the followings:

- ❖ Level of engagement: This signifies the grade at which stakeholders are actively involved in the development and implementation of urban sustainability initiatives. These findings in connection with the past study by Nielsen et al. (2019), imply that the level of decision-making capacity, and the degree to which stakeholders are involved in the implementation of the initiatives could impact positively urban sustainability.
- ❖ Diversity of stakeholders: This refers to the variety of stakeholders involved in urban sustainability initiatives, including residents, businesses, non-profit organizations, and government agencies. This was in the same opinions by Fernandez-Anez (2016) in that diverse groups of stakeholders are more likely to agree with the initiatives that reflect a range of perspectives and priorities, leading to more effective and sustainable outcomes.
- ❖ Resource allocation: The allocation of resources, such as time and funding, to support stakeholder involvement and participation in urban sustainability initiatives is crucial. The findings treaded the path of Zeng et al. (2022), which supports the notion that the more resources are allocated to support stakeholder involvement and participation, the more likely it is that stakeholders will be able to contribute effectively to the initiatives.
- ❖ Transparency and accountability: This is the extent to which cities' sustainability initiatives are transparent and accountable to stakeholders. Owojori and Okoro (2022) affirmed these findings, that the extent to which stakeholders are involved in decision-making, and the extent of feedback and reporting provided to stakeholders on the progress of the smart initiatives are important.
- ❖ Community support: The level of support for urban sustainability initiatives within the community can be measured by determining the extent of consciousness and comprehension of the initiatives among stakeholders. This was affirmed by Del-Real et al. (2023); in which the author stated that the degree of community involvement in urban sustainable initiatives, and the extent to which stakeholders are willing to take action to support the initiatives are paramount.
- ❖ Outcome measures: This finding refers to the actual outcomes achieved through urban sustainability initiatives, including lowered emissions of greenhouse gases improved water and air quality, and increased access to green spaces. Outcome measures can be used to evaluate the efficiency of stakeholder involvement and participation in achieving urban sustainability goals. By measuring these variables, as concurred by the study of Head (2008), it is possible to assess the level of stakeholder involvement and participation in urban sustainability initiatives and their influence on achieving urban sustainability goals.

6. Conclusion, implication for the study, and future research

The study contributes to knowledge of ICT in urban development in developing nations, particularly Nigeria. It highlights the importance of smart urban areas for addressing environmental issues and achieving the SDGs. Developing nations like Nigeria should embrace smart urban development and city innovation strategies, as ICT plays a crucial role in enhancing urban sustainability and residents' quality of life. Effective governance and regulation of ICT in smart cities are essential, promoting integrity, transparency, and citizen involvement. Similarly, smart city initiatives can address many of the issues confronting emerging countries, including the provision of basic services, economic development, and environmental sustainability. While there are challenges to implementing these initiatives, a collaborative and inclusive approach can help to overcome these obstacles and create smart cities that are inclusive, equitable, and sustainable. Thus, the upcoming generation could be compiled to utilize advanced technologies, to maximize health, efficiency, and integration of energy and resources in urban infrastructure systems. As the ICT contributes to urban sustainability by enhancing operational efficiency and improving residents' quality of life; it inferred that the use of data analytics and smart technologies would optimize resource utilization and create more efficient and sustainable urban systems.

Addressing challenges and risks associated with technology adoption in smart cities, such as data privacy and security, and bridging the digital divide for equitable access to technology, is crucial. Hence, this study presents a comprehensive approach to smart city strategies; through human-centered design principles and stakeholder involvement. Effective governance and regulation of ICT in smart cities are crucial, requiring policies that promote integrity, transparency, and citizen involvement. Inclusive and sustainable strategies, involving local communities and stakeholders, are necessary to realize the benefits of smart cities. Also, collaboration among stakeholders, including environmental experts, architects, planners, and researchers, is crucial to improve Nigeria's built environment and address environmental issues. Collaboration, inclusivity, and sustainability are keys to harnessing technology's potential for improving residents' lives and promoting sustainable urban development in developing nations.

This study presents several significant implications for researchers in the field of urban sustainability. The implication of the study for theory is vested in the necessity of Engineering Application Potential for the design, implementation, and impact of ICT-based initiatives in Nigeria's smart cities and buildings. Also, the implication of the study underscores the need for a more concentrated research focus on the relationship between information and communication technology (ICT) and urban sustainability. The study suggests that researchers should delve deeper into understanding how ICT can be effectively leveraged to support the development of sustainable urban environments. This involves exploring the various applications of ICT, such as smart city technologies, in both industrialized and developing nations. Additionally, the researchers should undertake further investigation into the dynamics of stakeholder engagement and its impact on sustainability outcomes. This could involve exploring different models of engagement, assessing the role of diverse stakeholder groups, and identifying best practices for effective participation.

The implications of the study extend beyond academia and have important ramifications for practitioners and policymakers involved in urban planning and development. Insights from this study can guide policymakers in promoting equity, inclusion, and sustainability in ICT-based initiatives. The research underscores the critical role of ICT in promoting urban sustainability. As a result, practitioners should prioritize the integration of ICT solutions into urban development plans and policies. This includes investments in digital infrastructure and the adoption of technologies that facilitate sustainable urban practices. Furthermore, the study places a strong emphasis on the need for stakeholder engagement in urban sustainability initiatives. Practitioners should take this as a call to action and design strategies that ensure active participation from diverse stakeholder groups. This might involve creating platforms for dialogue, consultation processes, and community engagement efforts to incorporate multiple perspectives into decision-making.

Also, governments and city authorities should consider allocating resources to develop smart infrastructure and technologies that not only improve the quality of life for urban residents but also address pressing environmental challenges. Policymakers and practitioners must prioritize strategies that ensure equitable access to the benefits of ICT-based urban environments. This involves addressing issues of accessibility, affordability, and the digital divide to make sure that all members of society can enjoy the advantages of sustainable urban living. Lastly, effective governance and management structures are crucial for the successful implementation of smart urban sustainability projects. Decision-makers should focus on creating transparent and efficient frameworks that facilitate the deployment and management of these initiatives while ensuring accountability and sustainability.

In the aspect of the study's limitation, as ICT is rapidly evolving, with new technologies and approaches emerging frequently; the study may not reflect the most up-to-date innovations and their potential impact on urban sustainability. Hence, future research should consider the dynamic nature of technology. In addition, future research can focus on understanding the long-term impact and scalability of ICT-based solutions in different contexts. With the increasing collection and utilization of data in smart cities, there is a need for research on data privacy and security. Future studies can investigate the challenges and solutions related to protecting citizens' data and ensuring the security of critical infrastructure in smart urban environments.

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CRediT authorship contribution statement

Oluwagbemiga Paul Agboola: Conceptualization, Data curation, Formal analysis, Visualization, Writing – original draft. **Faizah Mohammed Bashir:** Data curation, Software, Writing – review & editing. **Yakubu Aminu Dodo:** Data curation, Writing – review & editing. **Mohamed Ahmed Said Mohamed:** Data curation. **Ibtihaj Saad Rashed Alsadun:** Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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