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INTERNET OF THINGS AND ARTIFICIAL INTELLIGENCE: THE KEY TO SUSTAINABLE DEVELOPMENT IN DEVELOPING COUNTRIES

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Abstract

Aiming for sustainable development, the Conference of Parties and United Nations Sustainable Development Goals (SDGs) have been established in response to growing environmental issues like climate change and global warming. Integrating internet of things (Io.T.) and artificial intelligence (AI) technology has emerged as a key strategy that promises to revolutionize environmental sustainability and sustainable development strategies while maintaining the ability of businesses to compete economically. AI has the potential to improve energy management systems, optimize operational efficiencies and support data-driven decision-making, all of which are vital to the realization sustainable development. However, there are a number of obstacles to overcome before AI and IoT can be effectively applied to environmental sustainability programs, particularly in developing nations. These challenges include data scarcity, ensuring ethical deployment of AI technologies and cyber-crimes. This study focuses on how leveraging AI and I.oT helps to reduce environmental foot prints and aids in achieving the COP 29 goals. Lagos state, Nigeria being the commercial heart-beat of the nation having a teeming population of about 140 million people was chosen as the case study. The study adopts a qualitative methodology, which includes conducting expository interview and thorough literature review. Major stake holders in eleven medium-large corporate entities spanning Lagos state were interviewed to gain insights on the subject matter. Findings showed that implementing AI and IoT-based technologies improves operational effectiveness, minimizes environmental impact and guarantees the best use of already-depleting resources while optimizing output, underscoring persistent issues and the necessity of strong ethical and regulatory frameworks.

Keywords: Artificial Intelligence (AI), Internet Of things (IoT), Sustainable Development, Developing countries and Environmental Management Top of Form

1. Introduction

In an era where technology intertwines with everyday life, Internet of things (IoT) is the next wave of innovation and has emerged as a transformative force. The ability of IoT to collect, process, and transmit data in an economical and energy-efficient manner is a major factor in its success. IoT, being a grid of interconnected devices collects and exchanges data exponentially cutting across various sectors from engineering, medicine, policing, urban planning to agriculture. Scientists estimate that the IoT market will continue to develop at an exponential rate, which has already risen in recent years. This astounding growth is not just a testament to technological advancement but also reflects a paradigm shift towards more integrated and intelligent systems. At the same time, sustainability has become the crux of global discourse, prompting us to rethink our interaction with the environment.

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In this context, IoT presents an unprecedented opportunity by harnessing IoT's potential, we can optimize resource usage, lessen environmental footprints, and promote sustainable practices across industries.

Energy efficiency is becoming more and more important on a global scale due to its substantial benefits to the environment, economy, and society because sustainable energy is essential to national sustainable development, increasing its efficiency in transportation, industry and buildings could cut the world's energy consumption by nearly a third by the year 2050 while also assisting in the reduction of greenhouse gas emissions worldwide by promoting energy efficiency in buildings, manufacturing, and transportation (Raihan et al, 2022). An alternative perspective put forth by Bill et al. (2007); Hemeida et al (2022) holds that the two main pillars of sustainable development are energy efficiency and renewable energy. Stable energy efficiency is regarded as having national security in many nations because it encourages a decrease in energy imports, which slows the rate at which energy supplies are depleted. Goals for energy conservation and efficiency should be incorporated into national technology agendas and plans for economic restructuring as part of development strategies to promote greater advancement. In many countries, stable energy efficiency is considered as having national security because it prompts the reduction of energy imports thereby reducing the rate of depletion of energy resources. Energy efficiency and conservation goals should be integrated into economic restructuring plans, national technological agenda as part of development strategies to usher in greater advancement. Additionally, countries are prioritizing sustainable development by aligning their development goals for improving the economy, society and well-being with ecological goals, according to Eisenmenger et al. (2020). The Sustainable Development Goals (SDGs), which replaced the Millennium Development Goals (MDGs), were adopted in 2015. Therefore, while the 17 SDGs aim to balance social, economic, and environmental goals, the MDGs focused on improving well-being in the developing world.

The current threats to global sustainability, like biodiversity loss and climate change, are seen as the main forces behind international policy initiatives. The loss of biodiversity and climate change are two pressing issues facing global sustainability that should be addressed immediately and serve as the foundation for international policy (IPCC, 2018; IPBES, 2019). Climate change has evolved from a minor problem to a worldwide emergency that poses a threat to human life. In order to fulfill the goals of prior COP meetings, we must act right now to put the goals into practice on both a micro and large level. It is important to remember that the Sustainable Development Goals 2030 (SDGs 2030) are based on the primary goal of the COP26 meeting, which was to combat climate change. As a result, any deviation from the COPs' objectives also touches on the SDGs. An integrated strategy for sustainability, economic expansion, and a just human environment is necessary for climate resilient development. Climate wise agriculture, sustainable forest management, early warning and sharing systems, resilient infrastructure, soil and water conservation, and livelihood diversification are all necessary to stabilize the climate and advance toward sustainability. Realizing the importance of ocean's contribution towards climate change and scaling up of ocean-based strategies is also needed to accelerate net-zero carbon world as they are the natural sinks to CO_2. According to a global climate report released by the World Meteorological Organization (WMO) in 2021, sea levels have risen by 4.4 mm annually between 2013 and 2021 due to rising temperatures. One of the goals of COP26 was to phase out coal and to stop all countries from funding or providing subsidies to new coal-fired power facilities. According to a research by Welsby et al. (2021) published in Nature, over 90% of coal and 60% of oil and methane must remain unextracted in order to keep global warming to 1.5 °C. The report also states that by 2050, the world's oil and gas output must drop by 3% annually. Even though 23 nations signed the first-ever "COP26 Coal to Clean Power Transition Agreement" and more than 40 countries decided to stop using coal to generate electricity, some of the biggest coal producers were left out of the accord. Furthermore, it is now imperative to move quickly to phase out coal power and end subsidies for fossil fuels without any additional dilution. It is necessary to label packaged goods with the carbon footprint in order to raise consumer awareness of carbon emissions and how to reduce them. For evaluating sustainable development and calculating the environmental impact of output, Gross Carbon Footprint (GCF) and Gross Sustainable output (GSP) ought to be used in place of Gross Domestic Product (GDP) (Arora and Mishra 2019).

2. Literature Review

In recent academic debates, the incorporation of AI technology and I.o.T into environmental sustainability and sustainable development has become a crucial field of study. Researchers like Bibri et al. (2024) emphasize AI's ability to address pressing problems related to ecological conservation and carbon footprint reduction. Studies by Bachmann et al. (2022) and Aldoseri et al. (2023) highlight this technological change by highlighting AI's revolutionary effects on enhancing energy efficiency, streamlining supply chains, and enabling data-driven decision-making processes. These developments mark the beginning of a shift toward more sustainable business practices by drastically lowering greenhouse gas emissions and balancing ecological responsibility with financial demands (Shiu, 2023; Sjödin et al., 2021; Bocken et al., 2020; Gupta & George, 2020). Understanding AI's role in accomplishing sustainability goals becomes more important as companies throughout the world grapple with the challenges of climate change and environmental stewardship. Building on these fundamental discoveries, the paper explores how big businesses are using AI to lessen their environmental effect by implementing AI-driven carbon footprint reduction techniques.

Worldwide, there is a strong belief that energy efficiency is critical to national sustainable development. According to Soroka et al. (2019), energy efficiency reduces greenhouse gas emissions and other pollutants, which has significant positive effects on the economy, environment, and society. Driving national sustainable development involves reducing risks associated with uncertainties arising from fuel price changes and source depletion, as well as mitigating climate change. Furthermore, Dato (2018) found that energy efficiency can be a major factor in lowering the energy intensity of economic activity, preventing the need for enormous new supplies and lowering dependency on foreign fuels and potential price swings in energy (UNEP, 2009).

2.1. Theoretical framework

The theory of Ecological Modernization studies how policy changes can lead to more sustainable practices (Van Valkengoed & Van der Werff, 2022). The theory propositions that societies can transition toward greater environmental sustainability through a process of modernization that incorporates ecological considerations into economic and policy decisions. The theory advocates changes in societal standards jointly contribute to reducing environmental impacts. This study also uses the Resource-Based View (RBV) theory as a strong theoretical framework to describe how big businesses use AI and I.o.T to reduce their carbon footprints and improve environmental sustainability. RBV, which has its roots in the groundbreaking research of Wernerfelt (1984) and Rumelt (1984) asserts that a company's competitive advantage stems from its valued and distinctive resources that are difficult for rivals to imitate or replace (Musa, Ghani & Ahmad, 2022) According to this study paradigm, AI technologies are recognized as important, non-replaceable assets that help businesses develop long-term competitive advantages. Using RBV, the study explores how AI capabilities might be strategically integrated into business frameworks, enhancing organizations' ability to adopt eco-friendly practices. It explores the ways in which AI-driven innovations, like data-driven decision-making and energy-efficient procedures, support both profitability and ecological goals. The incorporation of IoT and A.I in sustainability efforts is evident across diverse sectors, demonstrating its vast potential in environmental conservation and resource management. In order to protect the "quality of life of future generations," sustainable development places a strong emphasis on "natural balance" while simultaneously aiming for "economic and social progress". According to (Cătoiu, Vrânceanu, and Filip, 2010), sustainability is the way of the future and that IoT has a significant impact on business. Recent research has examined the positive relationship between IoT and sustainability by renowned academics including Laine (2014) and Almufarreh and Arshad (2023). The emergence of the Internet of Things, which has many uses across several industries, has proven to be a huge benefit (Abu Ghazaleh and Zabadi, 2020). "From reducing water related disasters, economic losses, energy efficiency, effective water management, to better connectivity and decision making," the Internet of Things can positively impact any environmental issue (Salam, 2019). The need for a revised definition of sustainability is being driven by the Internet of Things' rapid expansion (Daj, 2016). The UN Sustainable Development Goals (SDGs) and the Paris Agreement's objectives can both be met with the aid of IoT (Salam, 2019; IoT Forum 2017). The corporate world is being forced by recent evolutions to add a new word to its lexicon: "globality" (Thrassou and Vrontis, 2009).

3. Research methdology

3.1. Study area

As shown in Fig. 1, Lagos State is a mega city in southwestern Nigeria with over 14 million people. It is the commercial heart-beat of the nation with vast concentration of national markets like Computer village at Ikeja, phone village at Ikeja, Balogun and

Tejuosho cloth and materials market, Motor and Vehicle parts market (Ladipo- Oluwole, Aspamda, Owode-Onirin (Ikorodu)), International Markets like Alaba, Auto-parts (Trade Fair), businesses, factories, ports and commercial ventures. More than 60% of the nation's commercial activities takes place in this state. Lagos state being part of the 36 states of Nigeria, is the second most populous state but the smallest in land mass area. Bordered to the south by the Bight of Benin and to the west by Benin for 10 km, Lagos State borders Ogun State to the north, making it the only Nigerian state to border only one other state. Lagos state is the most populous city in Africa. The state was formed from the Western Region and the former Federal Capital Territory on 27th May 1967 (Onyeakagbu, 2021).
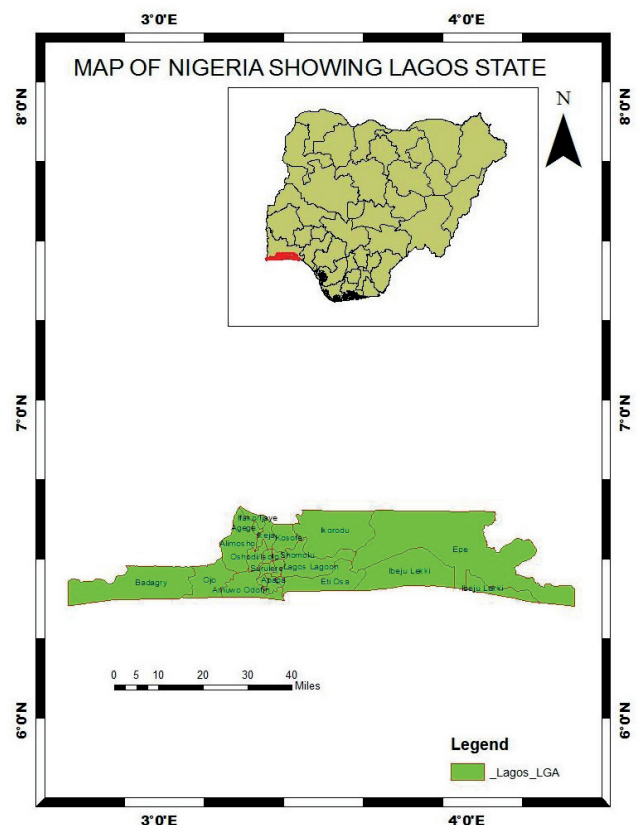

Figure 1: Map showing the study area, lagos state

Source: Authors field survey, 2024

Geographically, Lagos State is surrounded by bodies of water with the largest of these water body being Lagos and Lekki lagoons On land, non-urbanized areas are within the tropical Nigerian lowland forests region with natural areas housing a threatened populations of mona monkey, tree pangolin, and hooded vulture along with a transitory population of African bush elephants. The state is rich in bio-diversity with a rich population of flora and fauna with large fish populations along with African manatees and crocodiles (Amao et al, 2017). Lagos State is undergoing rapid urbanization owing to its teeming population and strategic geographical location, it is also a state of noteworthy culture, education and a promising transportation hub for Sub-Saharan Africa. Additionally, the state also has the highest literacy rate in the country. The state is noted for its bustling markets and significant economic activities despite

being threatened by overcrowding and chronic incapacitating traffic. The State has the highest Human Development Index in Nigeria and has a lot of on-going developmental projects. The state is endowed with natural resources like; Clay, Bitumen, Glass Sand and Crude Oil. Lagos is characterized with two climatic seasons namely; The Tropical wet season and the dry (savanna) season.

The study used a qualitative research methodology to examine how the Internet of Things (Io.T.) and artificial intelligence (AI) contribute to sustainable development in developing nations. Eleven participants who were purposively selected from a variety of medium-sized to major enterprises in Lagos State participated in the interviews. The interviews were done in-person using a flexible set of open-ended questions to examine how AI and IoT are affecting sustainable development activities, including the technology employed, the difficulties encountered, the effects seen and the trends expected in the future. The interview data was documented then analyzed using thematic analysis, which included transcribing, locating recurrent themes, grouping replies into thematic clusters, and interpreting the results to synthesize the findings. The study was conducted with rigorous adherence to ethical principles, such as informed consent, confidentiality and data protection. A thorough investigation of stakeholders' viewpoints regarding IoT and AI's contribution to sustainable development was made possible via scientific approach by guaranteeing the validity of the results and the depth of insights.

4. Results and discussion

In recent years, the incorporation of I.oT and AI technology into the operational frameworks of major enterprises has attracted a lot of attention. Organizations are investigating AI's new solutions in response to the pressing need to address environmental sustainability in the face of global climate issues (Bibri et al., 2024; Bracarense et al., 2022).

S/N	RESPONDENTS	DESIGNATION	SECTOR
1	Participant 1	Telecommunication personnel	Communications
2	Participant 2	Customer care officer	Banking
3	Participant 3	Security Expert	Security
4	Participant 4	Nigerian Brewery staff	Breweries
5	Participant 5	Realtor	Housing
6	Participant 6	Medical record officer	Health worker
7	Participant 7	Town Planner	Housing
8	Participant 8	Stock Broker	Stock Exchange
9	Participant 9	Loan officer, Micro-finance bank	Banking
10	Participant 10	Quality control officer (Grocery Bazaar)	Grocery store range
11	Participant 11	Environmentalist	Consultant to LASEPA

Table 1: Showing the sectors the respondents represent

Source: Authors firld survey, 2024

Participant 1: "Being a customer care executive with one of the leading communication companies (MTN Nigeria) in Nigeria, I would say the communication industry is heavily reliant of the application of internet technology and A.I is the brain. Within the last two decades the country has witnessed an outstanding revolution in the communication sector with the advent of E-mailing, social Media, video-calls, web hosting platforms, conference call platforms and so many other application. A.I and I.O.T have practically turned the world into a global village ushering in endless possibilities"

Participant 2: The introduction of E-banking has changed the course of banking in Africa, as the nation has evolved from the era of just depositing and withdrawing money with occasional loan disbursement as it was yester years! As a top tier customer care executive with one of the first indigenous banks (FBN) in the country, I have been involved in the banking sector for more than 3 decades and have seen it evolve first hand. The introduction of AIOT has greatly simplified interbank transactions and operations. Automated teller machines and point-of-sale (POS) systems have significantly simplified cash withdrawals and enabled transactions to be completed outside of the bank's physical location

Participant 3: As the M.D/ CEO of one of the top (leading) security outfits in town, I can say that the application of AIOT in surveillance and information gathering has revolutionized the industry making it possible to watch several places at once via internet connectivity (cameras and sensors) and has greatly improved response time to crime, also the area of forensics, database records and profile matching has also been greatly improved as well.

Participant 4: I have worked in the Nigerian breweries for decades and have seen the system upgrade from manually intensive inputs to almost fully automated systems with the human input being minimal thanks to the integration of AIOT from the inception of production on the production line to the finishing (packaging) of beverages.

Participant 5: As a professional, the housing sector as changed immensely with the introduction of smart homes having integrated computer systems that handle automated gates, heating, air conditioning, lightening, gardening systems, security systems and so on, the industry is witnessing a shift in preference with prospective clients opting for smart housing units.

Participant 6: AIOT application in health range from wearable like heart pace monitor to portable devices like electronic sugar level and blood pressure level monitors. Sophicated machines include CAT scan machines, MRI machines, Dialysis machines and so many more. The advent of this machines has made it possible to monitor patients' attributes, vitals and symptoms more accurately and in real time thereby saving lives thanks to advancement in technology. Also the integration of I.O.T with the medical records (database) has expanded the capabilities of medicine by eons.

Participant 7: The integration of AIoT is revolutionizing municipal administration through enhanced efficacy in waste management, public services, energy distribution and traffic regulation. Smarter urban infrastructure, better water cycles, and safer gas usage are some examples of applications that aim to build a more sustainable urban environment.

Participant 8: With the introduction of AIOT, crypto trading, forex, stock and bond trading has advanced to a new level since global

markets can now be accessed and synchronized online, resulting in job opportunities and business chances worldwide, guaranteeing financial advancement and ultimately sustainable development.

Participant 9: Sourcing and get loaning as become easier with advent of AIOT, credit organizations can leverage on existing database like National Identity management, Bank Verification Number systems to access customer information, verify address, work place and acquire contacts of friends and family in case of default or demise of the client, consequently entrepreneurs and SME's now have better access to loans promoting economic development as the loan processing period has been greatly shortened.

Participant 10: Grocery sales have reached a new level thanks to the integration of I.O.T. with sales merchandising. This is because the system allows for the collection of vital consumer feedback, which ensures that business decisions are sound and that additional investment is made in the right way. The development of artificial intelligence has also made it feasible to forecast sales and client requests.

Participant 11: Emphasized that using AIOT in environmental research was a step in a positive direction and highlighted a few benefits of AIOT implementation.

Opportunities and advantages of iot (Products & Applications)

AIOT technologies collect data through sensors and devices in various sectors, detecting environmental factors like temperature, moisture, and leaks, providing crucial information for decision-making and remediation efforts. IoT devices are transforming systems by responding to anomalies and predetermined circumstances, setting off alarms, stopping automatic procedures, and suggesting the best course of action to mitigate risks. This proactive approach is crucial for managing ecological systems effectively. This data-driven approach enables anticipatory and preventative maintenance and resource management thereby reducing carbon footprints. IoT aids in preventative maintenance and resource management strategies, promoting sustainability and reducing carbon footprints through data-driven approaches.

Energy monitoring, Smart Grids and Renewable Energy:

Participant 7 detailed that AIoT integration transforms city administration by improving efficiency in trash management, public services, energy allocation, and traffic control. In order to create a more sustainable urban environment, applications include safer gas consumption, improved water cycles, and smarter urban infrastructure. Given the rising demand for energy worldwide, IoT-based solutions offer instruments for improving energy management, cutting consumption, and encouraging environmentally friendly behaviors as purported by RBV Theory fully explained in the work of Wernerfelt (1984); Rumelt (1984) and referred to by Participant 1 in his interview. In addition to saving money and energy, this also helps the economy and the environment. Participant 7 buttressed the fact that utility firms may connect energy sources like micro-grids and solar panels with dispersed devices thanks to IoT technology to boost energy distribution efficiency, enhance connection and lessens reliance

on conventional energy sources. Customers will benefit from improved control over household energy use through mobile devices, which will increase sustainability and reduce energy expenses.

AI-Powered Carbon Footprint Strategies

Participant 4 opined that artificial intelligence (AI) will significantly reduce greenhouse gas emissions by improving energy efficiency, streamlining supply chains, and facilitating data-driven decision-making (Bachmann et al., 2022; Aldoseri et al., 2023). These technological developments promote a dual advantage of sustainability and profitability by supporting economic goals and ecological obligations (Shiu, 2023; Sjödin et al., 2021; Bocken et al., 2020; Gupta & George, 2020).

Application of A.I and IOT in manufacturing processes

The application of AI most especially, machine learning algorithms to improve industrial processes was emphasized by the participants. This technological application is essential for anticipating the need for equipment repair, which lowers energy consumption and downtime (Participant 4). This highlights how AI improves sustainability and operational efficiency through automation and predictive analytics (Bachmann et al., 2022; Aldoseri et al., 2023). By leveraging AI-driven predictive maintenance, organizations can mitigate operational disruptions and reduce energy-intensive practices. This underscores AI's role not just as a technological tool but as a catalyst for operational transformation aligned with sustainability objectives.

Buildings: Participant 5, pointed out the fact that allure of AIOT -enabled smart home appliances is irresistible even to those who wrote off smart home technology as an unattainable concept for lazy kids are now enamored by its usefulness, due to their growing creativity and intuitiveness, these gadgets will become extremely popular in the next years. He further stated that the benefits of smart homes go beyond home automation comfort and include security and family safety as revealed in the study of Dwivedi et al. (2020). Participant 7 affirmed that this kind of home sustainability manages energy usage and makes it possible to utilize renewable energy sources as efficiently as possible stating that other benefits include lower greenhouse gas emissions, less need for imported energy. The "Paris Agreement has displayed a clear signal to stakeholders and investors that the global transition to a low-carbon economy and clean energy will prevail for ages to come," as postulated by IPCC (2014). Users' preferences are studied by AIoT devices, which produces results that satisfy users and result in a considerable reduction in energy usage and prices for all subscribers. It has been stated that since its beginnings, this technique has saved billions of kilowatt hours of energy globally.

Optimizing Commercial Building and Energy saving Street Lighting: Participant 5 opined that commercial buildings with sensor and analytics platforms have more comfortable workplaces and lower energy bills (Fairchild, 2019). Through on-demand provision of intelligent lighting, cooling, and heating, these systems enhance work environments and support environmentally conscious initiatives. The switch to LED lighting, particularly in public spaces, is another significant development as iterated by participant 7, claiming that LED lighting uses

50% less energy than traditional lighting and buttressed by the study of Wang et al, (2014). Participant 10, added that up to 80% more energy may be saved by connecting these LEDs to a software-based management system (Dwivedi et al., 2019). This shift is essential in urban areas where a large amount of energy is used for lighting. The third participant pointed out the fact that improved community LED lighting significantly improves security as well (Grubler et al., 2018).

I.O.T application in health care: Participant 6 stated that the pandemic caused by SARS and COVID 19 has boosted the research and implementation of useful biosensors and systems capable of obtaining reliable information to prevent, detect, and mitigate the effects of the disease (Samson et al, 2020). A solution for monitoring patients with specific diseases such as diabetes using mobile devices is discussed in (Villarreal et al., 2014). Additionally, participant 10 noted that the COVID-19 pandemic contributed to the growth of AIOT in the supermarket industry.

Economic development: Participant 2 and 9 affirmed that with the advent of AIOT, sourcing and loaning have become easier. Credit organizations can use existing databases, such as National Identity Management and Bank Verification Number systems, to access customer information, verify address and workplace, and obtain contacts of friends and family in the event of a client's default or death. As a result, entrepreneurs and small and medium-sized businesses now have easier access to loans (Allen et al., 2021), which promotes economic development because loan processing times have been significantly shortened. Participant 4 detailed that with AIOT's sensors and software, waste and emissions might be decreased, improving efficiency, quality and cutting costs. Industry innovation centers can help firms grow. Participant 7 also iterated that AIOT can help address urban overpopulation caused by Rural-Urban migration by providing semiautonomous productive machines in rural areas. This technology allows people to participate in useful events worldwide, operating productive machines in an augmented reality environment.

AIOT in Banking and finance Institutions: Participants 2, 9 and 8 concur that AIOT technology is being used by a lot of businesses to improve operations, product development and fraud detection. Financial institutions can use anomaly detection to identify fraudulent or odd consumer behavior with the use of software called Behavioral AI for Financial Services as opined by Participant 2 and substantiated by Hernández et al. (2023).

Environmental Protection: Participant 11 detailed that the application of IoT technologies are an essential strategy for combating climate change by collecting environmental data through sensors in various systems. These systems detect factors like temperature, moisture, and leaks, providing crucial information for decision-making and remediation efforts, thereby enhancing environmental protection. IoT systems are crucial in sustainability initiatives, actively reacting to pre-determined conditions and analyzing data from sources like water treatment and energy flows. Participant 4 that AIOT technology enables predictive maintenance, resource management, and carbon footprint reduction, enhancing green technology and environmental impact. The IoT infrastructure has been modified to promote environmental sustainability

and safety, ensuring that regulations can be easily updated and adjusted without disrupting operations.

Key challenges or limitations in the application of smart i.O.T for sustainability in developing countries

A) EPILEPTIC POWER SUPPLY:

All of the interviewees agreed that power grid management systems are far from effective and that electricity generation levels in developing nations like Nigeria are still far below ideal. Since smart technology (I.O.T.) is highly reliant on power and requires a stable power source to operate well, the region's irregular power supply is a unique issue. Low power generation is a significant issue that prevents I.O.T. from realizing its full potential in the relevant sectors like transportation, agriculture, water management, pollution control, and so forth.

B) ERATIC NETWORK:

The notion that interconnectivity remains a major issue in developing nations like Nigeria due to the extremely inadequate and ineffective internet network was emphasized by participants 1, 2, 8, and 9. The poor quality of the internet greatly hinders the realization of the full potential of integration of smart technology (I.O.T) in relevant sectors such as transport, agriculture, water management, pollution control etc. as I.O.T relies heavily on the network (internet) as a connectivity tool to function and as such reliable network is essential for I.O.T technology to work effectively.

C) INCREASING DEMAND FOR ENERGY

The advent of I.O.T has led to an increase in energy demand worldwide, as the two ends of the IoT domain have very different power consumption needs. Compared to the number of IoT nodes, there are only a small number of cloud servers. These require a lot of electricity because they operate continuously. Today, the amount of cloud services in the world is constantly growing at an alarming rate. The IoT ecosystem has many node but most of them are in standby (sleep) mode most of the time except when they are receiving or sending data. AIoT devices and systems consume very little energy thanks to the stand-by (sleep) mode and all the interviewees agreed to this fact. Energy consumption doubles every four years or so. If this development continues, computers will theoretically consume more electrical energy by 2037 than is currently produced worldwide.

D) CYBER ATTACK AND CRIMES

According to Participant 3 and 8, the biggest challenge of IoT for any business is the security and privacy of data while transmitting from one device to another (Raza et al. 2021). Implementing IoT for sustainability while being promising, it is also complicated in ways that go beyond the application of technology alone. Participant 2, 8 and 9 agreed that the interconnected nature of IoT devices opens potential gateways for cyber-attacks. Participant 3 stated that from thier technical point of view, as the number of connected devices and sharing of information increase, so do issues. Security and privacy remain the top two issues (Dwivedi et al., 2020). As described by

Dwivedi et al. (2020), any bug in a single device can potentially affect an entire IoT system and compromise users' private data. Companies and thieves are making money from every kind of personal information (Labong, 2019). Malicious usage of their gadgets and data privacy are major concerns for users, what most people do not realize is how deeply identity theft can affect their lives. The effect of ID theft on victims is disastrous, taking hundreds of hours to clean up, being emotionally draining and leaving people feeling vulnerable (Weber 2015). Data is the new oil and data trafficking is becoming worse as internet fraud as yahoo-yahoo (internet scam) is now the order of the day in developing countries like Nigeria where young people devise plans and techniques to deceive other gullible internet users by breaking into their personal networks and sending money or credit. Addressing the prevalent cyber insecurity requires robust security strategies involving encryption, regular updates, and strong access controls which comes at a great cost adding to operational expenses.

E) INTER-CONNECTIVITY AND DATA MANAGEMENT

Participant 1 stated that a substantial challenge lies in ensuring interoperability among diverse IoT systems, leading to the adoption of open standards and middleware solutions for seamless communication. In addition, the deluge of data produced by Internet of Things devices necessitates efficient management approaches that include cloud storage and sophisticated analytics tools to handle and interpret data.

F) LONG TERM RETURN ON INVESTMENT

Participant 1 made mention of the fact considering the financial and economic aspect of IoT particularly the cost and long-term ROI, its implementation needs careful consideration. Organizations must evaluate areas where IoT could lead to substantial cost savings or revenue generation over time. Participant 11 stresses that environmental impact of IoT such as energy usage and resource consumption, raises concerns. However, in the words of Wang and Wang (2020) that energy efficiency fuels technological developments and is clearly realized by sectorial transformation and as such the adoption of energy-efficient devices and strategies to minimize electronic waste is critical.

G) REGLATORY USAGE SUCCESS

The first participant brought up the difficulties in implementing IoT due to skills shortages, data protection regulations, and regulatory compliance. IoT services are causing data trafficking, a revenue-generating crime. Users are unaware of the potential for identity theft, as they believe devices are private. Training staff and partnerships with IoT services are crucial to combat this issue, ensuring users' safety. However, there is no regulation for almost all consumer devices or the data they collect. Partner companies are often exempt from disclosure of user data, third parties, and storage methods. Companies may store data, but they have no legal grounds to sell or transfer it, resulting in a lack of transparency and security. Some companies are paying hundreds of thousands of dollars to pressure their governments to relax data privacy laws. Smart devices, like self-driving lawnmowers and smart heaters, enable companies to analyze user data for their benefit. However, the transmission of this information is not local to the user's device but is on the web

for communication with the cloud since the web is used to enhance the functionality of smart devices and enable data transmission. Companies face challenges in security and privacy, as the collection and transmission of user information are mainly invisible to ordinary users but can be accessed by others. The biggest challenges of AIoT are security and privacy risks, which can be easily exploited by those with access. The possibilities seem endless and the risks involved are not to be taken lightly.

H) LACK OF TECHNOLOGICAL KNOW-HOW (EXPERTISE)

Every participant in the interview acknowledged that the difficulty in finding sufficient technical personnel would arise owing to the technical complexity of the Internet of Things system, which necessitates highly skilled personnel for system monitoring and maintenance (Raza et al, 2021). In developing countries like Nigeria where illiteracy percentage is up to almost 40 %, availability of experts to run and manage the IoT infrastructure is indeed a problem and the expedient need to train local indigenous man power to take up this responsibility is highly required and is key to solving the problem.

I) LACK OF MAINTANACE CULTURE

All the in interviewees concurred that Nigeria, being one of Africa's most populous nations, has a maintenance culture that is almost nonexistent, which adds to the large number of abandoned vehicles, buildings, machinery, and other equipment scattered around cities. The main cause of this lack of a maintenance culture is the pervasive use of dishonest behavior by officials at all levels who are in charge of ensuring that infrastructures are maintained and operated correctly. In order to shortchange the government, the officials either conspire with contractors or pocket money intended for maintenance. Prioritizing maintenance optimally is crucial, especially in the face of poverty, as it can hinder the efficient functioning of infrastructure and potentially lead to its deterioration.

5. Conclusion

In the upcoming years, reducing the energy consumption of the Internet of Things sector will be a major issue for the industry because energy conservation pays off handsomely. In order to connect items to the Internet while using minimal amounts of electricity, researchers must continue their work. According to Sharma et al. (2021), the Internet of Things (IoT) must be autonomous, energy efficient and able of use all kinds of energy, including vibration, heat, and light. It's not only profitability that motivates IoT and A.I manufacturers devoting a great deal of time, resources, and energy to discovering ways for the IoT industry to spend considerable money, time, resources and energy to discover ways for IoT industry to reduce its energy consumption. Battery life, legal compliance, and environmental awareness are all important factors driving this trend. Radio communications lowers capital installation costs because it does not require cables and is lighter. Battery- free products have lower operating costs. Renewable energy production reduces environmental impact by eliminating the need for batteries replacement. The future of the Internet of Things requires battery-free end nodes powered by renewable energy, highlighting the growing role of energy harvesting. For example, to reduce the load on the

national grid, innovative methods for converting ambient energy to electrical energy have been discovered. The search for passive energy sources to power Internet of Things devices is ongoing, thus optimizing energy consumption and use. Prospective developments and trends in IoT for sustainability point to a future where sustainable practices can be greatly improved on a worldwide scale. In coming years, connected devices are expected to play a major role in driving change. The public and private sectors will demand more connected devices for better energy distribution, accurate business forecasts, the benefits of green IT, and solutions to many of the region's environmental problems. As a result, overall production gains are anticipated to soar. Manufacturers are facing a higher chance of data theft due to emerging trends in AI and the Internet of Things. To stay secure, they must invest in secure devices and adapt to these advancements to protect their devices. In summary, IoT and AI play a huge part in sustainable development that spans several industries and sectors, including farming, water management, recycling, and many more. As a result, comprehensive strategies that incorporate security, interoperability, data management, cost-effectiveness, environmental considerations, regulatory compliance, workforce development and user acceptance are necessary for an effective and sustainable IoT implementation. AIoT have the potential to play a significant role in community management and stability through the development of smart cities. Taking a comprehensive approach to these challenges is essential if we are to fully grasp the potential of IoT and A.I. in advancing sustainability.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Peer-review

Externally peer-reviewed.

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Conflict of interest

No potential conflict of interest was reported by the author (s)

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References and notes:

Allen, F., Gu, X., & Jagtiani, J. (2021). A Survey of Fintech Research and Policy Discussion. Review of Corporate Finance, 1(3–4), 259–339. https://doi.org/10.1561/114.00000007

Abu Ghazaleh, M. and Zabadi, A.M., 2020. Promoting a revamped CRM through Internet of Things and Big Data: an AHP-based evaluation. International Journal of Organizational Analysis, 28(1), pp.66-91.

Aldahiri, A., Alrashed, B., Hussain, W.: Trends in using IoT with machine learning in health prediction system. Forecasting 3(1), 181–206 (2021).

Aldoseri, F., Alhaddi, H., Chen, D., 2023. Leveraging Artificial Intelligence for Green Supply Chain Management: A Review. Journal of Cleaner Production 331, 129945.

Almufarreh, A., & Arshad, M. (2023). Promising Emerging Technologies for Teaching and Learning: Recent Developments and Future Challenges. Sustainability, 15(8), 6917. https://doi.org/10.3390/su15086917

Amao, J. O.; Oluwatayo, I. B.; Osuntope, F. K. (24 October 2017). "Economics of Fish Demands in Lagos State, Nigeria". Journal of Human Ecology. 19 (1): 25–30

Araral, E., 2020. Why do cities adopt smart technologies? Contingency theory and evidence from the United States. Cities, 106, pp.1-15.

Arora NK, Mishra I (2019) United Nations Sustainable Development Goals 2030 and environmental sustainability: race against time. Environ Sustain 2:339–342. https:// doi. org/ 10. 1007/ s42398- 019- 00092-y.

Bachmann, N., Tripathi, S., Brunner, M., & Jodlbauer, H. (2022). The contribution of data-driven technologies in achieving the sustainable development goals. Sustainability, 14(5), 2497.

Bibri, S.E., Krogstie, J., 2024. Artificial Intelligence (AI) for Sustainability: A Comprehensive Review. Sustainable Cities and Society 70, 102878.

Bill, P., Eldridge, M. (2007), The Twin Pillars of Sustainable Energy: Synergies between Energy Efficiency and Renewable Energy Technology and Policy. Available from: http://www.web.archive. org/web/20080505041521;

Bocken, N., Jonca, A., Södergren, K., & Palm, J. (2020). Emergence of carsharing business models and sustainability impacts in Swedish cities. Sustainability, 12(4), 1594.

http://www.aceee.org/store/proddetail.cfm?cfid=2957330&cftoken=50269931&itemid=432&categoryid=7.

Cătoiu, I., Vrânceanu, D.M. and Filip, A., 2010. Setting Fair Prices - Fundamental Principle of Sustainable Marketing. Amfiteatru Economic, 12(27), pp.115-129.

Chacko,A., Hayajneh, T.: Security and privacy issues with IoT in healthcare. EAI Endorsed Trans Pervasive Health Technol. 4(14) (2018).

Cristescu, C., Dumitrescu, C., Dulgheru, V., Popescu, T.C. (2017), Increasing energy efficiency and optimizing the operation of systems that produce clean energy from renewable sources. Hidraulica, 3, 62-73.

Daj, A., 2016. Economic and technological aspects of using IoT for sustainable environment

Dato, P. (2018), Investment in energy efficiency, adoption of renewable energy and household behavior: Evidence from OECD countries. The Energy Journal, 39(3), 1-2.

Dwivedi, Y. K., Hughes, L., Ismagilova, E., Aarts, G., Coombs, C., Crick, T., Duan, Y., Dwivedi, R., Edwards, J., Eirug, A., Galanos, V., Ilavarasan, P. V., Janssen, M., Jones, P., Kar, A. K., Kizgin, H., Kronemann, B., Lal, B., Lucini, B., ... Williams, M. D. (2019). Artificial Intelligence (AI): Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. International Journal of Information Management, 57, 101994. https://doi.org/10.1016/j.ijinfomgt.2019.08.002

Dwivedi, Y. K., Ismagilova, E., Hughes, D. L., Carlson, J., Filieri, R., Jacobson, J., Jain, V., Karjaluoto, H., Kefi, H., Krishen, A. S., Kumar, V., Rahman, M. M., Raman, R., Rauschnabel, P. A., Rowley, J., Salo, J., Tran, G. A., & Wang, Y. (2020). Setting the future of digital and social media marketing research: Perspectives and research propositions. International Journal of Information Management, 59, 102168. https://doi.org/10.1016/j.ijinfomgt.2020.102168.

Eisenmenger, N., Pichler, M., Nora, K., Dominik, N., Plank, B., Ekaterina, S., Wandl, MT., Gingrich, S. (2020), The sustainable development goals prioritize economic growth over sustainable resource use: A critical reflection on the SDGs from a socio-ecological perspective. Sustainability Science, 15(4), 1101-1110.

Fairchild, A. (2019). Twenty-First-Century Smart Facilities Management: Ambient Networking in Intelligent Office Buildings. In Computer communications and networks (pp. 271–289). https://doi.org/10.1007/978-3-030-04173-1_12

Grubler, A., Wilson, C., Bento, N., Boza-Kiss, B., Krey, V., McCollum, D. L., Rao, N. D., Riahi, K., Rogelj, J., De Stercke, S., Cullen, J., Frank, S., Fricko, O., Guo, F., Gidden, M., Havlík, P., Huppmann, D., Kiesewetter, G., Rafaj, P., . . . Valin, H. (2018). A low energy demand scenario for meeting the 1.5 °C target and sustainable development goals without negative emission technologies. Nature Energy, 3(6), 515–527. https://doi.org/10.1038/s41560-018-0172-6

Hernández, E. F., Membrillo, Y. E. N., & Aguilar, R. M. R. (2023). Importance of Artificial Intelligence (AI) in the Economy. Scientific Journal of Applied Social and Clinical Science, 3(19), 2–11. https://doi.org/10.22533/at.ed.2163192315086.

https://iotweek.org/internet-of-things-declaration-to-achieve-thesustainable- development-goals/> [Accessed 9 February 2024].

Hemeida, M. G., Hemeida, A. M., Senjyu, T., & Osheba, D. (2022). Renewable Energy Resources Technologies and Life Cycle Assessment: Review. Energies, 15(24), 9417. https://doi.org/10.3390/en15249417

Hosseinian-Far, A., Jahankhani, H. (eds.) Digital Twin Technologies and Smart Cities. IT, pp. 123–149. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-18732-3_8.

Intergovernmental Panel on Climate Change. (2014), Summary for Policymakers: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group 3 to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland: Intergovernmental Panel on Climate Change.

IoT Forum, 2017. Internet of Things Declaration to Achieve the Sustainable Development Goals,

IPBES. (2019), Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Bonn: IPBES.

IPCC. (2018), Summary for policymakers. In: Global Warming of 1.5° C. An IPCC Special Report on the Impacts of Global Warming of 1.5° C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty. Geneva, Switzerland: World Meteorological Organization. p32.

Labong, R.C.: Identity theft protection strategies: a literature review. J. Acad. Res. 4(2), 1–12 (2019).

Laine M., 2014. Defining and Measuring Corporate Sustainability: Are We There Yet? Social and Environmental Accountability Journal, 34(3), pp.187-188.

Leonidou, C.N. and Leonidou, L.C., 2011. Research into environmental marketing/management: a bibliographic analysis. European Journal of Marketing, 45(1/2), pp.68-103.

Lorenz, T. (2022). Soro Soke. https://doi.org/10.1017/9781009211840

Maksimovic, M., 2018. Greening the future: Green internet of things (G-IoT) as a key technological enabler of sustainable development. In: Internet of things and big data analytics toward nextgeneration intelligence, pp.283–313.

Musa, D., Ghani, A. A., & Ahmad, S. (2022). Resource Based-View Theory On Business Performance And Firm Strategic Orientation. International journal of education, Islamic studies and social science research, 7(1), 89-97.

Onyeakagbu, A.(2021). "5 most popular masquerades from across the various Nigerian tribes." www.pulse.ng Pp. 2-8, June 13, 2024 Retrieved 8/9/2021.

Petrakis, E.G., Sotiriadis, S., Soultanopoulos, T., Renta, P.T., Buyya, R., Bessis, N.: Internet of management. The case of IoT Wildfire Detection Systems. Bulletin of the Transilvania University of Braşov, 5, pp.171-184.

Popescu, S. M., Mansoor, S., Wani, O. A., Kumar, S. S., Sharma, V., Sharma, A., Arya, V. M., Kirkham, M. B., Hou, D., Bolan, N., & Chung, Y. S. (2024b). Artificial intelligence and IoT driven technologies for environmental pollution monitoring and management. Frontiers in Environmental Science, 12. https://doi.org/10.3389/fenvs.2024.1336088.

Raihan, A., & Tuspekova, A. (2022). Dynamic impacts of economic growth, renewable energy use, urbanization, industrialization, tourism, agriculture, and forests on carbon emissions in Turkey. Carbon Research, 1(1). https://doi.org/10.1007/s44246-022-00019-z

Raza, M.R., Varol, A., Hussain, W.: Blockchain-based IoT: an overview. Paper presented at the 2021 9th International Symposium on Digital Forensics and Security (ISDFS) (2021).

RENS21. (2014), Renewable 2014 Global Status Report, Technical Report. Paris: REN21 Secretariat

Rosales, M.: Distributing computing in the internet of things: cloud, fog and edge computing overview. In: Maldonado, Y., Trujillo, L., Schütze, O., Riccardi, A., Vasile, M. (eds.) NEO 2016. SCI, vol. 731, pp. 87–115. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-64063-1_4.

Rumelt, R.P. (1984) Towards a Strategic Theory of the Firm. Competitive Strategic Management, 26, 556-570.

Salam, A., 2019. Internet of Things for Sustainable Community Development – Wireless Communications, Sensing, and Systems. Heidelberg, Berlin: Springer.

Samson, R.; Navale, G.R.; Dharne, M.S. (2020). Biosensors: Frontiers in rapid detection of COVID-19. 3 Biotech, 10, 385.

Schneider, S., 2019. The impacts of digital technologies on innovating for sustainability. In Innovation for sustainability. New York: Springer, pp.415–433.

Sharma, K., Anand, D., Sabharwal, M., Tiwari, P. K., Cheikhrouhou, O., & Frikha, T. (2021). A disaster management framework using Internet of Things-Based interconnected devices. Mathematical Problems in Engineering, 2021, 1–21. https://doi.org/10.1155/2021/9916440.

Sjödin, D., Parida, V., Palmié, M., & Wincent, J. (2021). How AI capabilities enable business model innovation. Journal of Business Research.

Sophie, H. (2006), Invest in Clean Technology Says IEA Report. Available from: https://www.scidev.net/global/biofuels/news/invest-in-clean-technology-says-iea-report.html.

Soroka, L.C., Riabchenko, O.D., Zamryha, A.C., Korotun, O.C. (2019), State policy in the field of energy efficiency. Natsional'Nyi Hirnychyi Universytet. Naukovyi Visnyk, 4, 141-146.

things as a service (ITAAS): challenges and solutions for management of sensor data on the cloud and the fog. Internet Things 3, 156–174 (2018).

Thrassou, A. and Vrontis, D., 2009. A new consumer relationship model: The marketing communications application. Journal of Promotion Management, 15(4), pp.499–521.

UNEP. (2009), Energy Efficiency and the Finance Sector: A Survey on Lending Activities and Policy Issues. A Report Commissioned by UNEP Finance Initiative's Climate Change Working Group. Geneva: UNEP Finance Initiative.

UNFCCC. (2015), Adoption of the Paris Agreement UN: UN. Available from: https://www.unfccc.int/resource/docs/2015/cop21/eng/l09r01. pdf. [Last accessed on 2018 Feb 08].

Vega, M., 2020. Internet of Things Statistics, Facts and Predictions [2020's Update], [online] Available at: <https://review42.com/internet-of-things-stats/> [Accessed 7 June 2024].

Van Valkengoed, A. M., & Van der Werff, E. (2022). Are subsidies for climate action effective? Two case studies in the Netherlands. Environmental Science & Policy, 127, 137-145

Villarreal, V., Fontecha, J., Herv_as, R., Bravo, J., 2014. Mobile and ubiquitous architecture for the medical control of chronic diseases through the use of intelligentdevices: using the architecture for patients with diabetes. Future Generat. Comput. Syst. 34, 161e175.

Wang, X.C., Kleme_s, J.J., Long, X., Zhang, P., Sabev-Varbanov, P., Fan, W., Dong, X., Wang, Y., 2020. Measuring

Wang, C., Haider, F., Gao, X., You, X., Yang, Y., Yuan, D., Aggoune, H., Haas, H., Fletcher, S., & Hepsaydir, E. (2014). Cellular architecture and key technologies for 5G wireless communication networks. IEEE Communications Magazine, 52(2), 122–130. https://doi.org/10.1109/mcom.2014.6736752

Welsby D, Price J, Pye S, Ekins P (2021) Unextractable fossil fuels in a 1.5 °C world. Nature 597:230–234. https:// doi. org/ 10. 1038/s41586- 021-03821-8

Wernerfelt, B. (1984) A Resource-Based View of the Firm. Strategic Management Journal, 5, 171-180. https://doi.org/10.1002/smj.4250050207.