Enhancing Sustainable Development through the Application of Internet of Things (IoT) Technology in Nigeria

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Abstract. Internet of Things (IoT) like every other emerging technology is trending in the world of technology innovations and applications. IoT has continued to impact on the protection of the environment with the array of interconnected systems of digital sensors, appliances, smart city, smart watches and taken a leading role in sustainable development. This trend will be an enablement in the coming years. Sustainable development is a global concept and a process for sustainability (economic, climate, health, manufacturing, transportation, industrialization) and requires the deployment of highly efficient, reliable and hi-tech tools. These tools are the results of innovations and advancement in the field of Information and Communication Technologies (ICTs) of which IoTs are now being focused upon. IoTs have become the main driving force for sustainable development. In this research, the prospect of the application of this technology (IoT) was considered and presented as a recipe to the myriad of problems confronting sustainable developments of Nigeria's developmental programs. Key challenges of sustainable development are presented and attempts to overcome these challenges analyzed and how the technology could be applied to achieve sustainability.

Keywords: Internet of Things, Sustainable development, Smart City, Ecosystem, SDG, Sustainable education

Introduction

Internet of Things (IoT) like every other emerging is trending in the world of technology innovations and applications. IoT has continued to impact on the protection of the environment with the array of interconnected systems of digital sensors, appliances, smart city, smart watches and taken a leading role in sustainable development. This trend will be an enablement in the coming years. Brundtland (1987) defined "sustainability as development that satisfies the capacity of future generations, guaranteeing the balance between economic growth, care for the environment and social-wellbeing". In 1987, Brundtland (1987) Commission published a report which was also referred to as "Our Common Future" well elaborated for the United Nations and in it, warned against the negative environmental consequences of economic development and globalization. In the report, appropriate solutions were proffered to the problems caused by industrialization and population growth Brundtland (1987). Some of the identified challenges confronting the world today are the issues of climate change, water scarcity, poverty, unemployment, hunger and food production; thus an effective approach of promoting sustainable development could be a virile solution towards social progress, environmental balance and economic growth Anyasi et al. (2012) described Sustainable Development as a global concept and a process for sustainability (economic, climate, health, manufacturing, transportation, industrialization) and requires the deployment of a highly efficient, reliable and hi-tech tools. These tools are the results of innovations and advancement in the field of Information and Communication Technologies (ICTs) of which IoTs are now being focused upon. IoTs have become the main driving force for sustainable development.

Scope of Research

In this work, a qualitative and research oriented approach was used. The issues of application of IoTs towards Nigeria sustainable developmental plan are considered and data

sourced from various sources; the Internet, text books, and materials relevant to the study at the governmental level while previous works on the same subject would be reviewed. Suggestions and recommendations would be made towards the application of IoT for a sustainable national developmental plan.

Previous Works

Several researchers have worked on the application of Information and Communication Technology (ICT) on issues related to Sustainable Development (SD) in Nigeria. Anyasi (2012) discussed the role of ICT in promoting SD in Nigeria and emphasized the "significance of ICTs for sustainable development arising from the fact that it has been put into the mainstream of development in Nigeria (Anyasi, 2012). Information and Communication Technology (ICT) has become an integral part of developmental strides of nations of the contemporary World and its potentials cannot for change be over-estimated". Jones et al. (2017) outlined the "characteristics of the concept of sustainable development and how ICT relates to sustainable development, reviews a number of the ways two leading ICT companies, namely Ericsson and Microsoft and two industry bodies, namely the GSMA which represents the interests of mobile operators worldwide, and the Global e-Sustainability Initiative, believe they can contribute to the achievement of the SDGs as stated by the United Nations" (Jones et al., 2017). Jones et al. (2017) further reviewed a number of ways the Information Communication and Technology (ICT) industry believes it can contribute to the achievement of the SDGs and the possible challenges that could be encountered (Jones et al., 2017).

Muraleedharan(2019) investigated the role of IoT in sustainable development and concluded that "connected devices promise to be the major drivers of change within the coming few years and coupled with higher demands for this technology from both public and private sector for better energy distribution, accurate business forecasts, the fruits of Green IT and an answer to many of the environment challenges faced by the region, the overall production gains is expected to shoot up" (Muraleedharan, 2019). Again with the emergence of complex systems aided by Machine Learning and Artificial Intelligence will ensure IoT become more intuitive and user friendly and therefore the security of data by manufacturers of these connected devices will have to be reworked as the risk to data will also increase. Muraleedharan (2019) concluded that "amid all of these trends and predictions, the future ahead is definitely a promising one and certainly worth looking forward to" (Muraleedharan, 2019).

The Internet of Things Technology and Sustainable Development

The emergence of Internet of Things (IoT) is impacting on the economies. environments, transportation of developed nations of the world and has become a transforming agent of the digital technology towards enhancement of the way of life of their citizens (Figure 1). Although IoT is at the advancing stage, there have been several deployments of this technology globally that have started impacting the path to economic growth and accelerating human development with a change in the living conditions of millions of people the world over (Hewlett Packard, 2018).

Figure 1. The Internet of Things (Objects, Sensors and Devices)

Source: The Guardian 25th Nov., 2015 (https://guardian.ng/technology/preparing-nigeria-for-internet-of-things/)

Problem Statement and Challenges

In the report (FGN, 2012) by the Federal Government of Nigeria, presented at the United Nations Conference on Sustainable Development (Rio+20), the conference and other activities therein with "The theme, 'Green Economy in the Context of Sustainable Development and Poverty Eradication", the challenges of Sustainable Development in the National Context were highlighted. This include but not limited to the Economic, Social and environmental pillars of Sustainable Development as embedded in the Constitution of the Federal Republic of Nigeria (FGN, 2012).

The report (FGN, 2012) highlighted the challenges of Sustainable Development being faced as a Nation to include but not limited to (FGN, 2012):

i. Nigeria's economic growth in the past years.
ii. Growth in the agriculture sector, the main non-oil sector of the economy,
iii. Government recognizes that poverty and unemployment remain critical challenges to its efforts to enhancing the quality of life of the people.
iv. The Education Sector, sustaining and improving the Gross Attendance Ratio (GAR) and growth in adult literacy.
v. The health sector, Primary health services, Mortality rate etc.
vi. Urbanization - Nigeria ranks among the most urbanized countries in the world.
vii. Nigeria's environment is currently under increasing threat from natural and human-induced disasters such as drought, floods and erosion due to increase in population.
viii. Deforestation which is as a result of unsustainable felling of trees, housing for human survival is a major contributing factor to land degradation.
ix. Indiscriminate and Illegal mining activities in many parts of Nigeria, i.e. Ifewara in Osun State have resulted into making the land bare and unproductive.
x. Uncontrolled air and water pollution, indiscriminate liquid and solid wastes resulting from continued urbanization and industrialization in the country.

Ndubuisi-Okolo and Anekwe (2018) identified "Poverty alleviation, youth empowerment, entrepreneurship development, self-reliance and effective leadership as key strategies for actualizing the key components of sustainable development Agriculture, Environment, Economic, Education, Health, Urbanization, Social and Political in Nigeria"

(Ndubuisi-Okolo & Anekwe, 2018). Again, the United Nations at its 2015 Summit opined that, "Sustainable Development is channeled towards the achievement of nineteen solid objectives which include: No poverty, zero hunger, Good health, Quality Education, Clean water, Gender quality, Affordable and Clean energy, Decent work, economic growth, industrial innovation and infrastructure, reduce inequalities, sustainable cities and countries, responsible consumption, production, climate action, life below water, life below land, peace and justice, strong institution and partnership for goals" (Ndubuisi-Okolo & Anekwe, 2018).

IoT Technology for Sustainable Development

Having identified the areas of Sustainable Development in the context of the Nigeria state and her citizens, (Agriculture, Environment, Industrialization and Economic growth, Education, Health, Urbanization, Social and Political) the application of the IoT technology for the enhancement of this will now be considered (see Figure 2).

IoT and Sustainable Agricultural Industry

IoT-based farming in Agriculture, known as Smart Farming is a system that uses sensors or devices for monitoring the crop field (light, humidity, temperature, soil moisture, etc.) and automating the irrigation system (Savaram, 2020). Also described as precision farming (Bamigboye & Ademola, 2016), this method of farming (Precision Farming) uses data analysis to customize operations so as to maximize agricultural output based on variable inputs poised to transform the agricultural industry and enabling farmers to contend with the enormous challenges they face (Bamigboye & Ademola, 2016). Application of IoT in agriculture could be described as a revolution in the agricultural sector of the Nation's economy, tailored towards achieving increase agricultural products' output and economic gains to the farmers. Sustainable agriculture in Nigeria depends on the period/season. The climate in Nigeria is seasonal and farmers are engaged in cash and food crops alongside livestock farming done by private individuals and therefore, the importance of irrigation farming cannot be over-emphasized. Muraleedharan (2019) opined that smart and adaptive irrigation and agriculture systems in which the soil water content and nutrients are continuously tracked and appropriate actions are taken on the reported deficiency or damage are also gaining huge popularity among the farming communities (Muraleedharan, 2019).

IoT and Sustainable Environment

As a fallout from the Climate Change, environmental degradation has now become common occurrence all over the world. Nigeria's environment is currently under increasing threat from natural and human-induced disasters such as drought, floods and erosion due to increase in population. Again, the productive capacity of terrestrial and aquatic ecosystems of some nations of the world constitute a great danger to widespread loss of biological diversity. Air and water pollution, liquid and solid wastes associated with continued urbanization and industrialization in the country have impacted negatively to the environment (Dlodlo, 2012) and reduced access to essential environmental goods and services, including vital ecological processes such as water purification, nutrient cycling, control of pollution and soil erosion (Muraleedharan, 2019; Dlodlo, 2012; FGN, 2012).

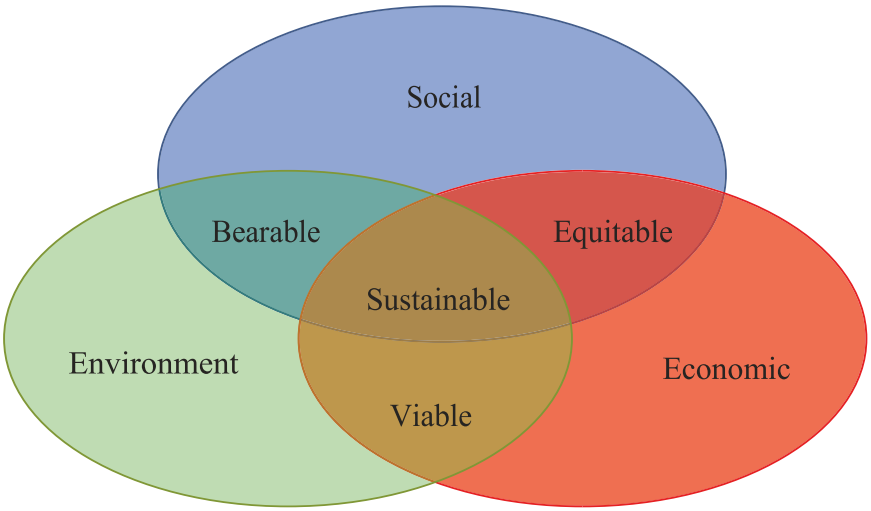

Figure 2. The Venn diagram of Sustainable Development
Source: Dupont et al. (2018)

In the Southern and Middle Belt zone of Nigeria, there is adequate quantity of water available for the population. However, there is the persistent problem of accessibility to clean and portable water in the rural communities of Nigeria with the problem distribution and effective monitoring to avoid wastage (Muraleedharan, 2019). IoT enables understanding of changes in water quality of a particular reservoir. The connection of different sensors and monitoring systems help in providing the water level and flood warnings as well as foresee other disasters such as earthquakes and potential landslides in prone areas, assisting the civilians and authorities to take drastic action on such issues (Muraleedharan, 2019). With about eight functional River basins and several other dams (mini and major), the management of the supply and distribution becomes glaring. IoT could be used to monitor the quality and distribution and preservation to avoid wastage. According to the United Nations Development Program (UNDP, 2020) around 74% of the poor are directly affected by land degradation globally and depend on forests for their livelihood. IoT could be used to trigger and avert disaster and degradation through early fire detection system and natural disaster such as fire, flood, drought and earth quake.

IoT and Industrialization – Sustainable Economic Growth

Nigeria faces several challenges in many sectors of her economy to which Internet of Things (IoT) can be gainfully applied to alleviate such specific problems in specific sectors and help to improve economic performance and social wellbeing of the citizens. In the manufacturing sector of the economy, IoT could be used to Monitor the production process for optimal production such as in the food packaging and production chain of the industry. The monitoring of vessels at the seaport, movement of goods and personnel, clearance of goods and other related activities at the port could be enhanced with the application of IoTs and reduced cost of handling. Transportation in the urban community, traffic control, reduction of air pollution, controlling the chain in the transportation of goods thereby enhancing economic growth could be achieved through the application of appropriate IoTs.

IoT and Sustainability in Education

The Internet of Things have the potential of enhancing and impacting sustainable educational system in Nigeria. Gone are the eras of virtual classrooms, Power point presentation etc. (Figure 3) IoT allows inter-connection of physical objects in the classroom.

Ralhan (2017) described Radio-frequency identification (RFID) as chips that can be used to tag as well as track physical objects (place at selected location on campus) or in the classroom irrespective of weather or other conditions (Ralhan, 2017) and Cloud-based applications can then be used to initiate analysis of data automatically such as IoT enabled boards, Student location, safety devices and attendance monitoring system (Ralhan, 2017). Equally, the Cloud support enables data to be stored and analyzed with results dispatched appropriately in real time and accessible by the devices. Tertiary Institutions in Nigeria are yet to reach out and be interconnected to each other and lectures have not been able to share data in real time between themselves. The application of IoT for sustainability education will benefit the sector in the following ways (Ralhan, 2017); supplementing textbooks, helping students with special needs, improving campus safety and security and increasing efficiency in the operational activities.

IoT and Sustainable Health Delivery

According to Mendis (2018) and SDU (2020), "a sustainable health and care system is achieved by delivering high quality care and improved public health without exhausting natural resources or causing severe ecological damage" (Mendis, 2018; SDU, 2020). It may also be useful to think about the relationship between sustainability and health in three distinct (Figure 4) ways moving from a narrow focus to a broad focus; a sustainable health and care system, Sustainable Health and Care Sector and Sustainable Health & Well-being (Mendis, 2018; SDU, 2020). The massive deployment of mobile and digital equipment, personal digital assistants (PDAs), and various forms of sensing devices based on digital and radio frequency identification (RFID) technologies has considerably impacted on the health sector and the healthcare environment (Turcu & Turcu, 2018). Connectivity between the different stakeholders, in the health sector has greatly been improved through the application of IoT infrastructure. This includes but not limited to the following; patients, medical staff, medical devices, intelligent wheelchairs, wireless sensors, mobile robots, etc. The advent of RFID multi-agent and Internet of Things technologies has opened and has improved people's access to quality and affordable healthcare services, improved patient safety and reduced medical errors (Turcu & Turcu, 2018). IoT will greatly enhance sustainability in Nigeria's health sector in the following ways (Libelium, 2019):

- Online Access – Provision of online access to medical services;
- Monitoring basic health parameters in case of chronic and highly contagious diseases;
- Educating the population in health self-management to streamline primary health care systems i.e. COVID-19;
- Promoting cloud access systems to clinical histories to facilitate the medical information of patients from any geographical point.

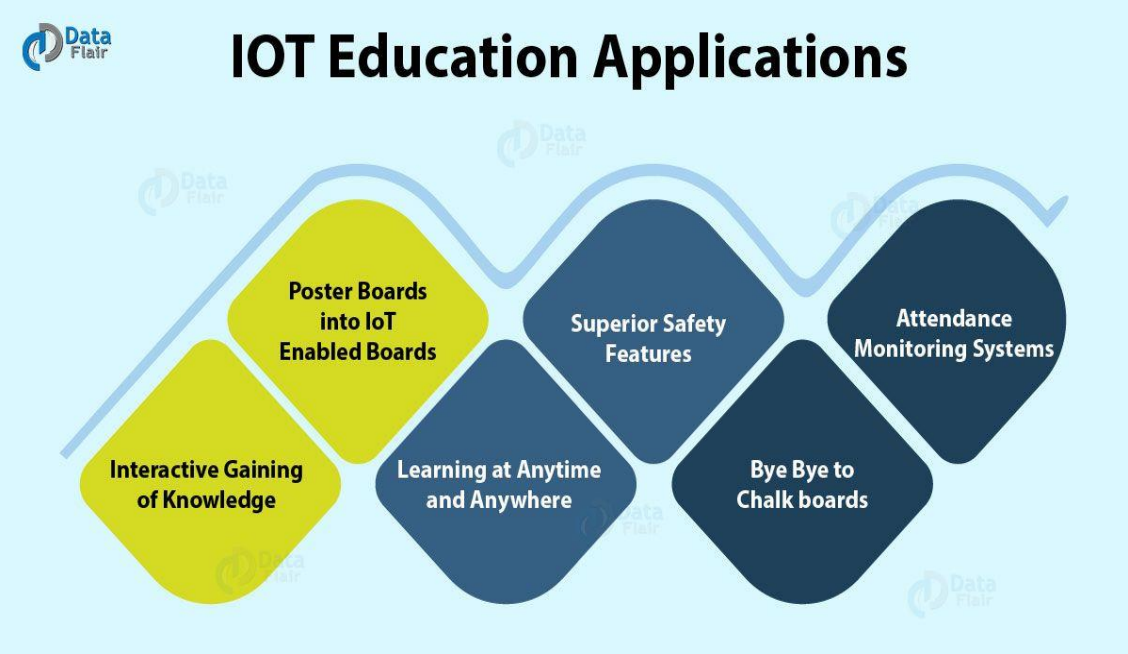

Figure 3. Roles and Application of IoT in Education
Source: DataFlair Team (Sept 15, 2018)

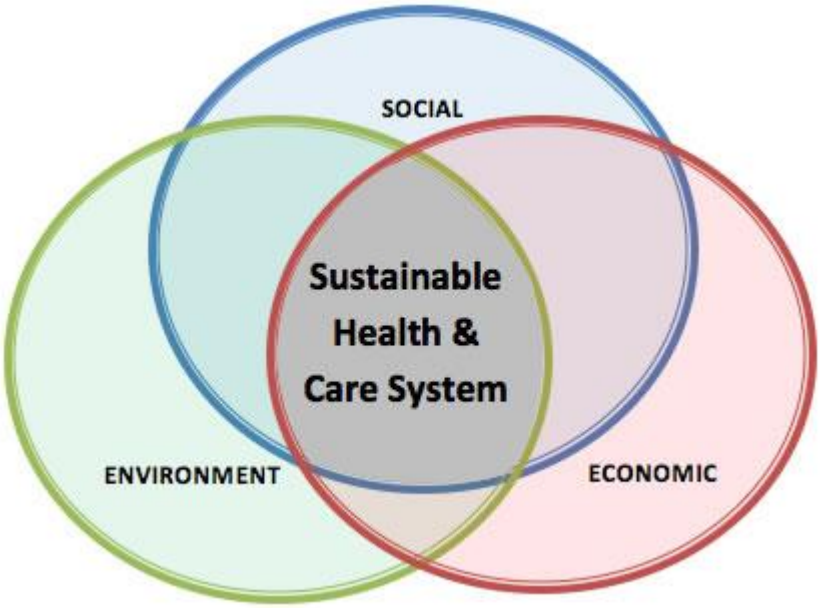

Figure 4. Health Care within the Context of Sustainable Development
Source: SDU (2020)

IoT and Sustainable Urban Centers

Ndubuisi-Okolo & Anekwe (2018) took a critical look at the population explosion in the country and concluded that it "vitiates the vision of achieving sustainable development in Nigeria. The quest for sustainable economy is not feasible without alleviating poverty drastically, empowering the youths, encouraging entrepreneurship education for effective self-reliance etc., considering the latest trending issues of the population explosion ranging from 139 million in the year 2005 to a whopping 189m in 2016" (Ndubuisi-Okolo & Anekwe, 2018). The population of urban centers in Nigeria is alarming as it accounts for at least 48% of country's total population of about 200m (Kolade, 2016). These urban centers are primarily

responsible for driving the nation's developmental strides economically and financially. Smart City strategies require innovative ways of interacting with stakeholders, managing resources and providing services. Disruptive and connectable technologies and IoT solutions for smart cities play important roles in transforming cities into smart cities which help in enhancing the quality, performance, and interactivity of urban services, optimize resources and reduce costs. The primary goal of the smart city is to strengthen the use of public resources, increasing the quality of services delivery and reducing operational costs. While this objective cannot be accomplished with the present mode of service delivery, leveraging the deployment of Internet of Things (IoT) within a Smart City can go a long way to reaching this goal (Adeejuwon, 2018; Meering, & Balella, 2016).

The following problems are often faced by urban-centres in developing countries of the world, Nigeria inclusive (Adamu, Wang & Adam, 2017);

i. Waste Management – There is no effective waste management and administrative system. For instance, in Lagos, Ibadan and several other urban cities waste dumps that constitute frightening health risks liter the commercial areas.
ii. Traffic Congestion in urban centers such as in Lagos, Kano, Porthacourt and Abuja could be resolved through the application of IoT by smart innovations in checking the activity clog in the city. Despite the fact that camera-based movement checking frameworks are as of now accessible and employed in numerous urban areas, low-control can give a bulk of data (Adamu, Wang & Adam, 2017).
iii. Smart Parking with a smart parking framework, nationals can discover a parking space quicker which implies less carbon emissions from the exhaust streams of the automobiles, lesser traffic blockage, and happier residents (Adamu, Wang & Adam, 2017).
iv. Smart devices often indicate the location and area of the parking lot unoccupied where drivers and vehicle owners can park their vehicles.
v. Smart Lighting in the streets of urban centers is in line with ensuring security, optimization of the street lighting efficiency and ease of life for the city's citizens. Specifically, this service can upgrade the road light intensity as indicated by the time of the day, the climate condition, and the presence of people (Adamu, Wang & Adam, 2017).
vi. Energy Consumption -The importance of energy to city service cannot be over-emphasized against its shortage (particularly in the developing world).

These problems could be addressed effectively using the deployment of IoT technology to transform the city into a Smart City and thereby change the living standard of the citizens. Some of the IoT solutions are (Libelium, 2019):

i. Environmental pollution can be reduced by favoring the creation of spaces that are more livable, greener, less polluting and more welcoming to its citizens
ii. Using the IoT harvested data to assist managers of administrations to make better decisions based on the data obtained to control waste level, clean water, irrigation water control, traffic control and thereby providing employment opportunities for our teeming youth.
iii. The Smart City concept and the IoT technology will improve the management of natural resources and public spaces and put them to gainful use.
iv. Boosting the tourist attraction of visitors to sustainable destinations through the promotion of environment monitoring in a smart tourist destination.
v. Waste and water management, environmental pollution control, smart and intelligent systems are those that would fit into a smart city
vi. Generating new business models for big-data exploitation of smart cities projects

Conclusion

Internet of Things (IoT) technology should now be considered as the major driver for sustainable development in Nigeria as a developing nation. Simply put, IoT will allow the measuring and controlling previously unconnected things reaching people and objects in the physical world that technology could previously not reach and in the process also supporting the national sustainable development programs. From the foregoing the application of IoTs to key areas of certain sectors of the economy for sustainability holds the key to a sustainable future in Nigeria. Eradication of hunger, poverty, unemployment, food production, accelerated health system, education, environment, water and waste management are areas that will be greatly impacted with this technology.

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