Internet of Things and Road Safety: Challenges and Opportunities for Africa

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Abstract

Based on Traditional Literature Review (TLR), the researchers explored IoT in the context of Africa. The study resorted to convenience sampling to select a representative sample of the previous studies to be reviewed. The paper specifically explored the IoT challenges and opportunities for Africa. The purpose of the study is three-fold, that is to identify areas where IoT can be applied in the domain of transport in Africa; identify areas where IoT can be applied in the domain of transport in Africa and also showcase the potential role that IoT can contribute to transport management in the continent. The research is important especially with regards to achieving sustainable transport systems across Africa. The study established that IoT challenges in Africa include lack of expertise in IoT, financial problems, power supply, high poverty rates, illiteracy as well as low internet penetration rates. The study also found out that IoT opportunities in Africa include the availability of ubiquitous wireless networks, alternative energy technologies and widespread usage of smartphones as well as the availability of IoT applications in road network management, road safety management, road traffic management and cross-border transport management. The results of the study imply that Africa still has a long way to go in terms of harnessing IoTs for improving road safety and yet there are a lot of opportunities presented by IoTs. Guided by the study, a nine-point policy prescription has been suggested. However, the research focused on the African continent and yet it would have more robust if country specific case scenarios were taken into account.

Keywords: Africa; Internet of Things (IoT); IoT challenges; IoT opportunities; road safety.

1. Introduction

The 4th Industrial Revolution triggers the concept of the Internet of Things (IoT) (Kwange *et al*., 2021). The term IoT was postulated by Kevin Ashton in 1999 in the context of supply chain management (Gubbi *et al*., 2013). Today the term IoT has evolved as a key word of modern technology (Miazi *et al*., 2016). The imminent wave of connected devices, appliances, sensors and countless other "things" represent the next generation of a hyper-connected world, called the IoT (Shin, 2014; Turkanovic *et al*., 2014). IoT refers to the use of intelligently connected devices and systems to harness data gathered by embedded sensors and actuators in machines and other physical objects (GSM Association, 2014; Ndabuaku & Okereafor, 2015). IoT are multiple devices that are connected to the internet via various communication networks, such as Wi-Fi and these can be sensors, home systems, applications and so on (Shapiro, 2017). The IoT is a triumph of distributed computing systems having a huge compatibility to compile, process and distribute information using wireless and wired communication systems (Miazi *et al*., 2016). IoT is a network of smart objects that have the capacity to automatically organize, share information, acting or responding in the face of circumstances and variation in the environment (Kamdar *et al*., 2016). The IoT is an integrated system that is able to cope with highly dynamic global network infrastructure; having the capacity of configuring themselves in line with standard communication protocols, where every single "thing" has its own identity and intelligent interfaces for seamless integration into information networks (Miazi *et al*., 2016). In its most basic form, the IoT is built on a network of distributed micro-devices embedded with various sensing abilities, which are used to monitor the environment and send the information between devices and end users (Xu & Mcardle, 2018). IoT implies that more people are now interconnected with various devices, making communications between the physical world and the cyber world possible (Muronga *et al*., 2019). Hence, IoT is an internet of three things namely, people to people, people to machine/things and things/machine to things/machine; interacting through internet. Figure 1 and 2 below are an illustration of the IoT:

Internet of Things

Figure 1 Internet of Things
Source: Patel & Patel (2016)

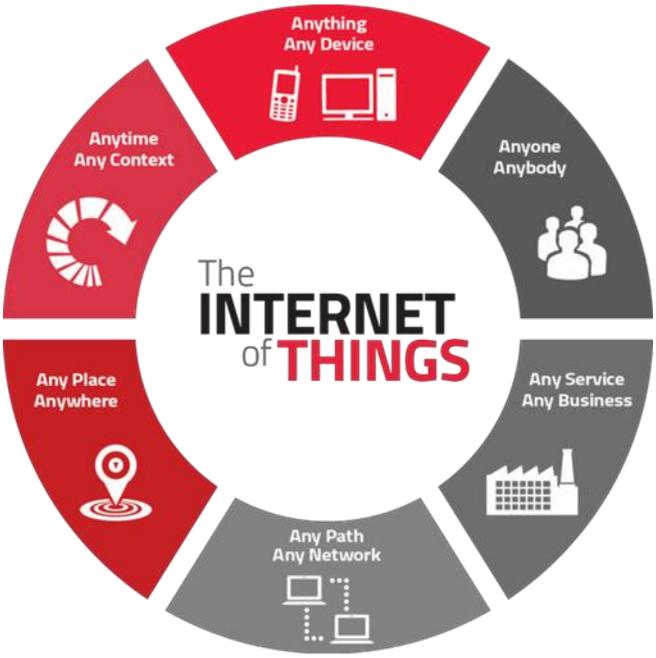

Figure 2 Internet of Things
Source: Patel & Patel (2016)

IoT can also be viewed as a network of networks as shown below:

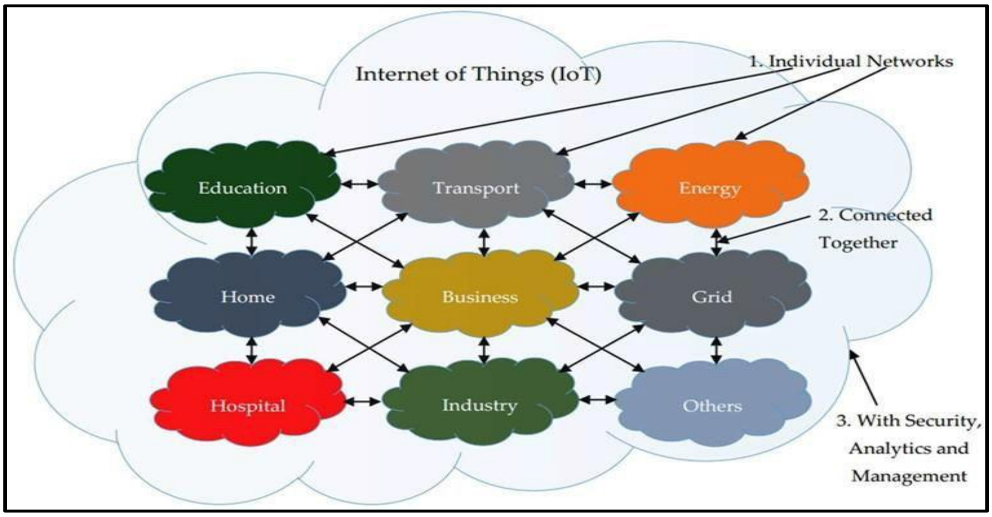

Figure 3 Internet of Things
Source: Hussein (2019)

In the transport domain this involves connectivity of a range of infrastructure, vehicle to vehicle communication, vehicle to personal mobile devices, vehicle to infrastructure and so on (Kwange *et al*., 2021). In the first place, IoT was presented in automobile industries to merely provide different information and entertainment applications with the aim of providing a comfortable driving experience and luxury journey (Balfaqih *et al*., 2022). According to Sankar & Booba (2020) the benefits of integrating IoT technology with transportation systems include:

- Distance can be travelled by the vehicle is optimized giving the benefits by reducing the fuel consumptions leading to the better profits in day-to-day activities;
- Optimizing or redirecting the best possible routes during the deadly and dangerous conditions;
- Through centrally intelligence controlled network, a service can be operated based on the demand or user request;

- Public transportation and logistics are centrally connecting networks through a control of traffic based on the vehicle count;
- Goods and cargo material can export, import, purchase and other shipping details can be maintained effectively;
- Transportation and logistics revenue can be improved for the company owners.

Other benefits include:

- Transport managers can monitor their fleets' flow velocity in real time. This makes it much more easier to warn drivers about speeding and other incorrect behaviours;
- Drivers are able to receive updated information on the road, traffic and weather conditions, real-time information about vehicle's pressure and temperature of tyres, fluid levels, deterioration and battery state. This is essential particularly in reducing breakdowns and therefore, prevent crashes;
- IoT technology also allows a company to reroute vehicles to the most efficient routes, immediately after the original route is blocked by an accident;
- With more advanced IoT technologies such as 5G, vehicles can now communicate between themselves in real-time, and hence result in fewer collisions and emergency breaking maneuvers.

Nowadays, the IoT is increasingly being harnessed to enhance the safety of drivers and passengers (Balfaqih *et al*., 2022). Indeed, there is overwhelming evidence which suggests that IoT systems detect, localize, report, model and analyze road crashes (Chung & Recker, 2012; Porte *et al*., 2016). It also contributes to smart parking, autonomous vehicles, smart traffic control, smart routing, traffic light sequencing, smart road lighting, bike sharing and public transformation (Xu & Mcardle, 2018). There is a growing interest in the potential of the IoT technologies to support transportation systems not only in Africa but also across the world. The main contribution of this study is to showcase the potential contributions of IoT to the domain of transport in Africa.

Relevance and Timeliness of the Study

Transport is a driver of economic growth of any country (Babazadeh *et al*., 2009; Nwakeze & Yusuff, 2010; Hong *et al*., 2011; Pradhan & Bagchi, 2013; Peter *et al*., 2015; Sharif *et al*., 2019; Okechukwu *et al*., 2020), hence the need to manage it effectively and efficiently (Dlodlo, 2015). This need is apparently in line with the need to achieve sustainable transport systems across Africa. This paper proposes and argues for the adoption of IoT in road safety management in Africa. With the right implementation of IoT technology, Africa can mitigate road traffic risks, prevent damage, reduce costs and save lives. The deployment of IoT technologies in Africa is envisioned to help the region in gathering the much needed information, making the necessary predictions and investigations and also reaching decisions that will make African roads safer. Furthermore, we all understand that in every country, there are rules and regulations that enforce safe driving. But while rules and regulations are rather reactive in nature and force drivers to drive safely to avoid resultant consequences, IoT plays a more proactive role in encouraging drivers to adopt safe driving habits.

Research Questions

i. What is IoT?
ii. Where does IoT fit in transportation in general and specifically in road safety?
iii. What are the IoT challenges and opportunities for Africa?

Objectives

i. To identify areas where IoT can be applied in the domain of transport in Africa;
ii. To identify IoT challenges for Africa;
iii. To showcase the potential role that IoT can contribute to transport management

Overview of IoT Development in Africa

Many African nations, just like other developing countries elsewhere, have already taken advantage of IoT technologies; from utility service providers to allowing healthcare providers to track the health of outpatients. In fact, the transportation industry is under-going a significant transformation, and the IoT is playing a significant role in making daily transportation efficient, safe and secure. Since the on set of the COVID-19 pandemic, there has been a marked increase in the general penetration and adoption level of IoT across the transportation sector not only in Africa but also worldwide. However, the African region remains markedly slower in embracing the IoT concept compared to most developed nations. IoT adoption is now indeed a discipline of great interest. IoT applications were initially primarily used in vehicle tracking but quickly moved into mobile payments and even smart cities. Countries such as Kenya and South Africa have taken the lead in IoT adoption. Other African countries are also embracing these technologies: Rwanda is using SIM cards to connect point of sale terminals in remote areas enabling merchants to accept credit or debit card payments. Endangered black rhino in eastern and central Africa are being given an ankle collar that is connected to the global IoT network and which relays movement and exact geo-location data back to anti-poaching teams. In Tanzania, IoT has been used to prevent pilferage of oil in the heavy transportation sector. Tanzanian heavy transportation sector companies had to adopt the Radio Frequency Identification (RFID) in order to address oil pilferage while oil was in transit. This resulted in a very significant decline in cases of pilfering of the oil that the trucks and tankers were carrying. Closer to Zimbabwe, in South Africa, the E-toll system called the Open Road Tolling is meant to collect tolls electronoically without human intervention since there are no physical booths in the highway, the Gauteng Highway, for example. With this kind of IoT, traffic jams and road traffic crashes have been reduced dramatically. By the end of 2014 the IoT in the developing world totalled 128 million, or 52% of the global numbers (GSMA, 2014). The figure has been forecasted to rise up to 60% or 575 million – by 2020. Slow internet penetration rates in Africa militage against IoT adoption. Nevertheless, McKinsey (2014), predicted that by 2025 Africa will have tripled its internet penetration to over 50%. Before there is widespread adoption of the IoT in Africa, there needs to be more security, trust and reliability. Connectivity , telecommunication coverage and power are other major challenges faced in the continent. Additionally, the region's lack of requisite infrastructure, generally expensive hardware, as well as limited technological background are all issues they experience surrounding the deployment of IoT.

2. Methodology

A Traditional Literature Review (TLR), a "traditional" way of reviewing literature, which basically involves gathering together a volume of literature in a specific subject area and synthesizing it (Cronin et al., 2008); was conducted through making use of four electronic scholarly databases, namely, IEEE Xplore, ScienceDirect, Web of Science as well as the Directory of Open Access Journals (DOAJ). TLR can also be viewed as a comprehensive, critical and objective analysis of the current knowledge on a topic (Baker, 2016). TLR is well known for being skewed towards a qualitative rather than a quantitative interpretation of prior knowledge (Sylvester et al., 2013). The major purpose of TRL is to give the reader a comprehensive background for understanding current knowledge and uncovering the significance of new research (Cronin et al., 2008). One of the primary advantages of TLR is that it can inspire research ideas by identifying gaps or inconsistencies in a body of literature, thus enabling researchers to determine research questions or formulate hypotheses. Additionally, TLR can also be used as educational articles to bring practitioners up to date with certain topical issues (Green et al., 2006). This study followed the four basic TLR steps, namely, choosing a review topic, literature search and screening, data extraction and analysis and writing the literature review (Levy & Ellis, 2006). In order to provide clear answers to research questions posed in this study, an initial literature search was conducted on the above mentioned scholarly databases as well as the Google Scholar search engine. The second stage involved direct content search from African countries' governments and industry databases, and this was used to find content relevant to IoT challenges and opportunities in the context of road safety in Africa. The literature search was conducted using key words, such as; IoT solutions in road safety, IoT application in road safety, IoTs in Africa, IoTs in developing countries, IoTs, IoT Challenges, as well as IoT Opportunities. Inclusion criterion included that studies must have been published in English, within the last two decades, must be original and must be open access while the exclusion criterion was that the studies were not peer-reviewed, and are reviews. A number of articles were accessed from various sources already mentioned. The researchers relied upon convenience sampling to select a sample size of fifteen articles amongst the previous studies to be reviewed. For each downloaded article, or source document, the title and abstract were read and judged for either inclusion or exclusion based on study objectives.

3. Analysis and Results

IoT Opportunities for Africa

IoT has many opportunities in transportation industry and these include various applications or needs of a transportation. Using IoT vehicles, can be monitored with respect to their movement, location, whether it is on running or stopped, or at any repair, and so on. All these aspects can be closely monitored intelligently using the IoT systems (Sankar & Booba, 2020).

1. Ubiquitous Wireless network

Wireless networks such as Wi-Fi have become more affordable and more accessible (Ndubuaku & Okereafor, 2015). There has been a general decline in average broadband data prices across Africa. Countries with the lowest internet prices include Sudan, where a gig of broadband data costs $0.9, followed by Egypt $1.30, Morocco $2, Rwanda $2.10, and Cameroon $2.20. It costs $2.30 in Algeria, $3.28 in Senegal and $4.80 in Cote dIvoire (Benhaddou, 2021). Unfortunately, in Zimbabwe, eight gigabytes of private internet data generally costs around $18 (Moyo, 2021).

2. Alternative energy and ultralow power technologies

Countries such as Egypt, Ethiopia, Kenya, Morocco and South Africa have shown firm commitment towards accelerated use of modern renewable energy or the socalled green energy, and are leading energy transition efforts, while some of the continent's countries such as Cape Verde, Djibouti, Rwanda and Swaziland have also set ambitious renewable energy targets. Other countries such as Zimbabwe are following suit, and renewable energy is on the rise across the continent. For instance, Africa has shown great progress in the development of its solar energy markets over the recent years, with the continent experiencing a growth of over 1.8W of new solar installations, mainly driven by five countries; Egypt, South Africa, Kenya, Namibia and Ghana (Obonyo, 2021). Availability of power to supply most devices that require automation has been a challenge in Africa but new technologies for energy harvesting, ultralow power devices have been a key enabler to IoT. Some devices today can power themselves as they tap energy from immediate environment. For instance, wearable devices for body monitoring (temperature and heart rate) can power themselves with energy from vibration, pulse and heat (Ndubuaku & Okereafor, 2015). This is an opportunity for IoT to monitor especially the health of the driver for safety purposes.

3. Widespread use of Smartphone

Over the past few years, smartphone use has really increased across the world. In fact, technology has become the foundation of progress. Because of its increasing importance, people all over the globe have also increased their use of technology in order to keep up with the changing times. This is particularly true in countries with developing and emerging markets, where technology use is defined by the number of people who use either the internet or a smartphone. In other words, technology users in these countries are catching up to countries with more developed economies (World Atlas, 2018). Slowly but surely, mobile phone penetration in Africa is improving. There are 747 million SIM connections in sub-Saharan Africa, representing 75% of the population (Roxana, 2019). Smartphones have become a remote control or interface for most applications ranging from healthcare to automobile. Also, the number of smartphone users has increased since the past years. Smartphone penetration per capita in Middle East and Africa will have experienced an increase of 13.6% from 2.6% in 2011 (Lopez Research, 2013). The affordability of the smartphone has also aided its spread in Africa (Ndubuaku & Okereafor, 2015).

4. Road Network Management

Monitoring of Road Conditions

Attached to a Global Positioning System (GPS), an electric-powered, three-wheeled unmanned ground vehicle BearCat III detects potholes using a video frame grabber. Through an internet capability, the BearCat III can communicate the coordinates to the responsible centre (Ghaffari *et al*., 2004). The GPS coordinates are obtained via satellite, and the video information obtained is transmitted to the responsible centres via the same channel. The detection of potholes through pattern recognition techniques and communication from the pothole to BearCat III is done wirelessly. Another system, Nericell, performs sensing using smart phones. The sensing component relies on the accelerometer, microphone, GSM radio and GPS sensors in the phones to detect potholes, bumps, braking and honking and report back to a server for aggregation (Mohan *et al*., 2008). Indeed, IoT can go a log way in terms of monitoring road conditions. In fact, IoT sensors and the so-called smart cement, that is, cement equipped with sensors; can monitor the structural status of roads and bridges under dynamic conditions and alert relevant authorities about deficiencies before they de-generate into catastrophes. In this regard, IoT road sensors can provide concerned authorities with real-time information about traffic and road conditions in the IoT-equipped regions.

5. Road Safety Management

Pedestrian visibility

A pedestrian detection system, such as Pedestrian Detection Safety Features in cars helps the driver to see better during bad visibility. Pedestrian detection technologies work using a combination of cameras, radar and lidar sensors. Through sensors attached to them, vehicles or cars sense their surroundings and identify appropriate paths that avoid obstacles. These can be sensors to detect heat intensity of the human body, or items of clothing they put on for visibility. Indeed, these technologies allow the driver and car to react appropriately.

Safety awareness education

StreetSmart, an integrated project in Baltimore in the United States of America sends location-specific messages to high-incident communities through broad-range media coverage. Information detailing the realities of pedestrian safety is brought to citizens' attention via radio and Television (TV) public safety announcements, coverage in blogs and websites, electronic advertisements and newspapers. IoT technologies such as StreetSmart present an opportunity for African countries in terms of road safety management.

Law enforcement on the roads

There are a number of IoT devices, for example, the Passive Alcohol Sensor (PAS), can assist in law enforcement on the road. For example, some IoT devices like PAS are used to control alcohol abuse. Sensors that measure blood alcohol content by smelling one's breath have always been around since 1938 when the Drunkometer was invented. Through IoT, in New Mexico, they use the Driver Alcohol Detection System for Safety (DADSS) to control alcohol abuse and enhance road safety. The IoT technologies can be adopted across Africa and can go a long way in avoid road traffic crashes as a result of drinking and driving.

Tyre pressure monitoring

One of the common causes of road accidents is tyre bursts and or failure. Though IoT it is possible detect if a tyre has sufficient tread depth. The software deduces the actual tread depth from the gradual changes in the tyre's rolling behaviour over time and enables drivers to recognise early enough when a tyre is run down to below tread depth required to maintain safety and displays a warning at the dashboard. Furthermore, indirect tyre pressure measurement sensors (TPMS) perform the same purpose by measuring air pressures by monitoring individual wheel rotational speeds and other signals available outside the tyre itself. Direct TPMS use pressure sensors on each tyre and give feedback to the vehicle's instrument cluster or corresponding monitor. This is technically known as intra-vehicle IoT. Some tyre pressure monitoring systems monitor the tyre pressure as well as tyre temperature.

Speed control

These days, through the use of IoT, speed can be measured in many ways. Mobile phones in a car transmit their location to a mobile phone network. By measuring and analysing network data, traffic information can be derived. Detectors mounted along the road, can detect a unique serial number for a device in the vehicle. Travel times and speed are also calculated by comparing the time at which a device is detected by pairs of sensors placed apart. Video cameras are another form of vehicle detection that can be used in road safety. Video detection systems have the capacity to automatically recognise number plates of a vehicle. Cameras then feed into processors that analyse the characteristics of video images as vehicles pass. The cameras are normally mounted on poles close to the road. A speed control system connects to a map at a control centre and if there is any violation, the dot on the map beeps. The central control may then clicks on the map and redirect to the audio communication of the vehicle. The violation is also automatically noted into the system database. In countries such as Zimbabwe, the onset of the COVID-19 era has been associated with significantly high numbers of road traffic crashes. This poses an opportunity for law enforcement agencies to deploy measures, including speed control systems to ensure road safety.

Response to emergency

With increased awareness of public emergencies, the need for clear communication for first responders and the ability for them to efficiently navigate city streets has come into great relief. Through the use of IoT an emergency call can be generated manually by vehicle occupants or automatically via activation of in-vehicle sensors after an accident. An emergency call carrying both voice and data directly to the emergency point is immediately dispatched. This is one area where IoT have paved way for better post-crash victim management and thereby enhancing road safety.

Car maintenance

Though the use of IoT, the car literally knows when it needs maintenance done and when it needs fuel. Sensors on components of the vehicle automatically detect the state of components and suggest replacements as soon as possible to avoid downtime. The sensors in the car and location services on technicians' tablets constantly send data to the company's many IoT monitoring systems, which are in turn fed into analytical software programs that come together on one dashboard to flag what needs to be done, sometimes before it is needed. Google's car maintenance reminder is an all in one car application that helps to keep track of mileage, fuel and efficiency, as well as log services and get maintenance reminder when a due date appears. The application sends a reminder for oil change, tyre rotation, wheel alignment, air filter change, belt replacement, spark plug replacement, and so on.

6. Road Traffic Management

Traffic management IoT devices provide guidance on the condition of the road network. They detect incidents and emergencies, implement strategies to ensure safe and efficient use of roads networks and optimise the existing infrastructure. Incidents can be unforeseeable or planned, for example, accidents, road works, adverse weather, holiday traffic peaks, and so on.

Accident investigation and recording

IoT is about collection and analysis of big data. When big data is properly stored, sorted, searched and analyzed it becomes intelligence and can be used to improve understanding of what is happening including frequency, trending and impact analysis and to provide tools necessary to manage resources, minimise impact and reduce road traffic crashes. Crowd sourcing collects voice messages, video and photos from the public to create data picture that is essential to road traffic management. A web based application such as the NASA's InvestigatorDisaster; provides data storage, management and analysis capabilities to accident investigation teams.

Road network policing

In licence and registration checkpoints, police may carry handheld devices which connect to a traffic control centre. Through the use of IoT, they can scan the bar code of the driver's licence or vehicle registration document. The information is then transmitted to the control centre wirelessly for comparison with the data held in the database. The outcome or feedback is communicated back to the handheld mobile device.

Education and training

The car driving simulator is developed for driver training schools especially in developed countries. The simulator is composed of hardware and a direct interface between the user and the immersive 3D world. The results are automated, implying that there is a guarantee that the learner has gone through all the routines. Defensive driving lessons to strengthen the driver's responsiveness and adaptability or to avoid occurrence of traffic crashes in adverse conditions is also simulated.

7. Cross-border transport management

Fleet management

Telematics can be thought of as the blending of computing and wireless communication technologies. Based on GPS satellite positioning and GSM cellular communication, telematics allows an efficient transport management through processing of all data transmitted by the vehicles (such as acceleration, distance, type of road, braking, impacts, real-time vehicle location and fuel consumption) in order to save time, money and provide a better service. It also provides real-time visualisation and tracking of all fleet vehicles including trip log, real-time tracking, driver behaviour, route monitoring, alerts and fuel management. Real-time information can be accessed through mobile, tablet and desktop devices. Telematics companies such as Geotab use IoT to help fleet management companies to significantly reduce road traffic crashes.

Challenges for Africa

1. Low Internet Penetration Rate

It is expected that by the year 2050, Africa will have a population of about 2.4 billion people (IMF, 2020). It is also argued that Africa will be the next big emerging market. With an internet penetration rate of 16% in Africa and eight out of the 10 countries having the world's lowest internet access rates, there are major barriers to the adoption of the IoT. However, there is clear growth potential. Consulting firm, McKinsey (2015) estimates that by 2025 Africa will have tripled internet penetration to over 50%, or around 600 million people, and as it does not have the same extensive infrastructure as Western countries, it can adapt its cities for IoT solutions more easily. Kenya has the highest internet penetration rate in Africa with 87.2 percent of the population connected to the internet.

2. Security, Privacy and Trust Issues

IoT security is a topic that is still in its development stage, though there exists a rather large volume of research that analyzes the challenges it presents and possible means of safe guarding against attacks. Since IoT architectures can be complex and can scale to accommodate billions of objects or things that interact with each other and with other entities, such interactions must be secured. IoT threats are numerous and include attacks that target various communication channels, denial of service, identity fabrication, physical attacks, and so on. The sheer number of nodes involved in an IoT network that creates information can be a large threat to privacy. Users involved in a sensor system or network should have tools provided to them that caters for anonymity amid connected networks. This will afford users a means of trust. Awareness mechanisms should be put in place that can detect intrusions and even prevent them. This will aid IoT objects in protecting them or even gracefully degrading their services. Recovery services must be able to determine areas under attack and redirect the systems' functionality towards trusted areas in an IoT network (Miazi *et al*., 2016).

3. Illiteracy

There has been significant progress in increasing adult literacy rates across Africa in recent years. Despite these advances, the World Bank (2014) estimates that 37% of the adult population still lack basic literacy skills, equivalent to over 170 million people. In addition to basic literacy, digital literacy—the ability to effectively and critically navigate, evaluate and create information using a range of digital technologies—is also significantly lacking amongst the population in the region and must be addressed. Also, there needs to be adequate user education on privacy and security of their "things". This will involve understanding how to issue permissions and access to their connected "things".

4. Lack of and or low levels of expertise

A great challenge is the lack of technically knowledgeable personnel. They include Engineers, Scientists and Technicians. IoT is a state-of-the-art term and implementing the technologies to build up IoT platforms requires learned personnel. In developing countries, the number of research centres is very low. The funding and investment to innovations is critically at nadir (Miazi *et al*., 2016).

5. Power Supply

Owing to the fact that things move around and are not connected to a power supply, their smartness needs to be powered from a self-sufficient energy source. Most batteries and power packs are either so heavy, hence, making the entire system bulky or they have a short lifespan and require frequent replacement or charging. Unfortunately, battery technology is making relatively slow progress, and "energy harvesting", that is, generating electricity from the environment (using temperature differences, vibrations, air currents, light, and so on), is not yet powerful enough to meet the energy requirements of current electronic systems in many application scenarios. There are some battery-free wireless sensors that can transmit their readings a distance of a few meters. Just like RFID systems, they get the power they require either remotely or from the measuring process itself, for instance, by using piezoelectric or pyro electric materials for pressure and temperature measurements. Solar energy is set to become the biggest trend. Installing slim and transparent solar panels on phones, cars and even buildings has already started providing consumers to keep going without ever having to worry about looking for the nearest plug.

6. Financial Challenges

The IoT provides a great opportunity for developing countries to leapfrog from poorly prepared to scientifically and technologically equipped countries which can use the IoT technology to face their current and future challenges by tapping into the potential provided by this technology. However, such opportunity may become reality only if Africa is ready to embark into this technology at the same pace as scientists and technologists of the developed world and financial challenges related to these technologies are addressed (Miazi *et al*., 2016).

7. High Poverty Rate

Africa is the poorest continent on Earth. A majority of the worlds poorest countries today are in Africa. Of course some African countries like South Africa and Egypt are not quite as poor as others like Somalia and Ethiopia. And though in recent years absolute poverty in Africa has shown some slight falls, African income levels have actually been dropping relative to the rest of the world. So poor Africa has been getting relatively poorer on average, and 2014 saw North East Africa again having starvation for millions in the region now especially affecting Somalia, Sudan and South Sudan - and in Somalia religious war has been worsening the famine situation there (World Poverty, 2022). IoT uses technology to connect physical objects to the internet. For IoT adoption to grow in Africa, the cost of components that are needed to support capabilities such as sensing, tracking and control mechanisms need to be relatively inexpensive in the coming years.

8. Weather/ Climatic problem

This can impair or affect the interconnectivity of the IoT components. Weather problems can be classified under natural disasters and though they cannot be completely eradicated, there has to be some preventive or corrective measures put in place. When there are weather threats looming, sensitive devices can be temporarily turned off and notification sent to users pending when it is resolved, this action may prevent greater loss than having to replace such devices (Atzori *et al*., 2010; Mattern & Floerkermeier, 2010).

4. Conclusions

IoT is indeed a novel paradigm that is rapidly gaining momentum in the era of modern pervasive computing. Just like in other sectors such as health, agriculture and mining; IoT technologies are also applicable in the transportation sector. Given the high prevalence of road traffic crashes in developing countries, including those from Africa, it has become necessary for African countries to adopt, embrace and implement IoT for road safety. While the study demystifies the term IoT and explains it relevance to transportation, the researchers also identify the challenges and opportunities posed the IoT in the sector, specifically for Africa. It is possible for Africa to leapfrog ahead of developed nations in embracing IoT. Based on this study, the following practical recommendations have been suggested:

i. There is need for adoption of effective alternative sources of power such as Wind and Solar, or the so-called green energy. In this regard, countries such as Zimbabwe are advised to rely on low energy data centers which can be powered by Solar energy which is abundant. Countries such as South Africa, Egypt, Ethiopia, Kenya and Morocco are advised to explore both wind and solar energy. This will go a long way in solving the problem of power outages. In Zimbabwe, solar powered street lights have been adopted. In the same manner, IoT infrastructures such as solar powered traffic cameras ought to be adopted for road safety purposes;
ii. There is need for African governments to train Engineers and scientists on IoT and also conscientize final users on the benefits that they can obtain from using IoT in road safety;
iii. African countries ought to increase investment in IoT for road safety. This can be done by attracting Foreign Direct Investment (FDI) as well as private sector investment in IoT for road safety;
iv. African governments are encouraged to properly administer road user charges (distance based charges, time based charges, tolls, transit charges), special purpose road user taxes and fines (vehicle taxes, fuel taxes, green taxes, fines), all purpose taxes (general taxes) as well as development cost charges (commercial areas access contribution and urban development contribution), as these are essential sources of finance that could be invested in IoT for road safety purposes;
v. There is need for African governments to increasingly engage in Private-Public-Partnerships (PPPs)[1] in speeding up the adoption and implementation of IoT for road safety projects. In this regard, the private sector can be harnessed to finance IoT infrastructure development through concessions[2];
vi. There is need to build trust in IoT devices for road safety. Trust is essential to realize the full potential of IoT;
vii. Digital literacy is one of the basic building blocks for promoting the adoption of IoT for road safety. All drivers, for example, must be able to use electronic technology in their car for safety and security of passengers and the automobiles. In this regard, African governments, through their relevant transport ministries; should train drivers in IoT and how this can be harnessed to improve road safety and save lives;
viii. Sensitive IoT devices may need to be temporarily turned off when there is bad weather in order to prevent damage. Proper repair and maintenance is also required for effective performance of IoT infrastructures;
ix. The wave of IoT development and adoption in Africa is being compromised by rampant poverty and hence the need for reducing poverty across the continent. This can be done by:
    a. Providing access to technology, internet and affordable energy, especially in rural areas;
    b. Developing and implementing sustainable economic growth policies and programs, in areas such as health and education;
    c. Improving management of water and other natural resources;
    d. Engaging in trade as a path out of poverty. This can be done by utilizing the African Continental Free Trade Area (AfCFTA) whose major aim is to boost intra-African trade by providing a comprehensive and mutually beneficial trade agreement among members states;
    e. Creating and improving access to jobs and income and also developing entrepreneurial talents.

The study is only restricted to the African context. It would have been more comprehensive and robust if it also covered other developing countries in other continents. The research was going to be more interesting if country specific case scenarios were taken into consideration in the analysis. However, the practical recommendations of the study can be adopted even in developing countries outside the African continent. Future research may focus on factors affecting the adoption of IoTs in the transportation sector and how these IoTs can be effectively harnessed to significantly improve road safety in Africa. As already noted by Green et al. (2006), one of the limitations of the TLR approach used in this study is that the selection of information from primary articles may be subjective and may also lack explicit criterion for inclusion. On the other side of the same coin, the TLR

[1] According to the World Bank (2014), a PPP is a long term contract between a private party and a government entity for providing a public service or asset, in which the private party bears significant risk and management responsibility and remuneration is linked to performance.
[2] A concession is a legal arrangement in which an organization obtains from the government the right to provide a particular service.

technique is most suitable in studies such as this one because it goes a long way in not only inspiring research ideas in IoT but also uncovering the significance of new research endeavors and innovations in IoTs for transportation.

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