The Smart City: Trends and Evolution, Readiness and Adaptability in Africa

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Abstract:

This paper reviewed and provides clarifications as to the meaning and concept of Smart Cities with particular reference to the Smart City Components. The paper also discusses Internet of Things and the Big Data in relation to the role they played in the development and evolution of smart cities. The paper further provides discussions on the 5G Wireless Networks and Industry 4.0 buttressing their significance in the smart cities concept. The paper as the name implies; discusses on the readiness and adaptability of this trending concept 'Smart City' in the African global space.

Keywords: Smart City, Internet of Things, Big Data, 5G Wireless Networks, c

1. Introduction

As Africa faces development trends, we ask how technological advances can trigger a digital revolution through the growth of smart cities. It is no doubt that, this emerging concept 'Smart City' has come to stay. According to Jean-Michel Huet (2016)[1], by 2040 Africa will be a home of 2.4 billion people and technological advances are the best answer to her challenges. Equally, they might also represent the new frontier of opportunity for an innovative Africa that will favor cities over rural life.

However, it will interest you to know that hitherto, there is no any clear and concise definition of the concept of Smart Cities in both the Practitioners and the Academia arena. This lack of clear-cut definition of the Smart City concept deemed this paper to present the definition of the concept in a number of concise ways.

According to (Mohanty, Choppali, & Kougianos, 2016) in a simplistic explanation, a smart city is a place where traditional networks and services are made more flexible, efficient, and sustainable with the use of information, digital and telecommunication technologies, to improve its operations for the benefit of its inhabitants. Smart cities are greener, safer, faster and friendlier. It is from this definition, the authors opined that smart city initiative will not only enhance Africa development with sustainable economic development and high quality of life, but it will as well be excelling in multiple key areas; economy, mobility, environment, people, living, and government.

Fig. 1. Smart City initiatives and concepts (SYSTEMA).

(Caragliu, Del Bo, & Nijkamp, 2009) , are of the opinion about the definition of a Smart City as thus; "A city can be defined as 'smart' when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic development and a high quality of life, with a wise management of natural resources, through participatory action and engagement." According to International Telecommunication Union, smart city can be defined as "an innovative city that uses information and

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communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects." Indeed, the importance of these cities growing, and the United Nations has put together a taskforce to create a key performance indicator for global smart sustainable cities index. In commemoration of World Cities Day, 2017, "Innovative Governance, Open Cities" emphasizes the implementation of the global New Urban Agenda and the 2030 Agenda for Sustainable Development through the creation of livable, sustainable cities conducive to inclusive growth and development. To this end, smart city initiatives in Africa can be key tools toward achieving her regional goals.

In quest to put the concept in a better perspective (Harrison et al., 2010) opined in their article entitled "Foundation for Smarter Cities'' concisely states that: the term "smart city" denotes an instrumented, interconnected and intelligent city. "Instrumented" refers to the capability of capturing and integrating live real-world data through the use of sensors, meters, appliances, personal devices, and other similar sensors. "Interconnected" means the integration of these data into a computing platform that allows the communication of such information among the various city services. "Intelligent" refers to the inclusion of complex analytics, modelling, optimization, and visualization services to make better operational decisions (Harrison et al., 2010).

This paper is organized and presented in the following manner: Section 1 is the introductory part of the paper, presenting some variant definitions of smart city. Section 2 is the Literature review; with sub-section 1 discussing on the smart city components, sub-sections 2 and 3 discusses about the impacts of 5G wireless networks and Industry 4.0 on the evolution of smart cities respectively, while sub-section 4 talked about Internet of Things and the Big Data. Sections 3 and 4 forms the discussions and summary parts of the paper respectively and finally Section 5 concludes the paper.

2. Literature Review

The use of technology is changing everyday life for people in cities, and city is evolving to meet their needs. This is nothing new. But the pervasive nature of digital technology means that this global change is impacting people's lives at an unprecedented pace. In order to have a sound understanding of this emerging concept of "Smart City", it is imperative that the article educates the reader with the various components that Smart City is composed of smart infrastructure, smart transportation, smart energy, smart healthcare, and smart technology (Mohanty et al., 2016).

The number of city facilities required as a function of city population can be calculated as follows:

$$Nf = (Rp/Year)(1\ Year/D\ Days)(1\ Hour\ /Nc\ People)(1\ Day/H\ Hours)$$
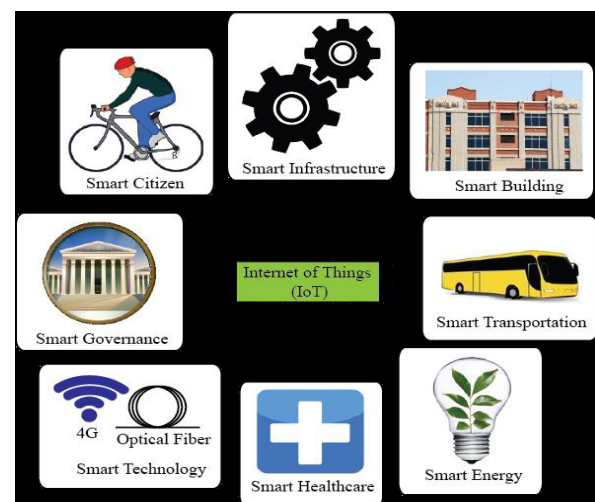
Where,

Nf - is the number of facilities,

Np - is the city population in millions,

Rp - is the rate per person use in year/week,

D - *is* days per year,

Nc - is the customers per hours, and

H - is the hours per day(Mohanty et al., 2016).

**Fig. 2.** A broad Overview of the Smart City Components. (Mohanty et al., 2016).

2.1. Smart City Components

I.   Smart Infrastructure

To cope with the increasing population in Africa, as well as to ensure economic, security and environmental stability, state capital cities in Africa are now focusing on becoming smart cities. Smart City is a concept of utilizing technologies and connected data sensors to enhance and become powerful in terms of smart infrastructure and city operations. Hence, it is important leveraging Africa

solutions for smart cities. Africa cities with smart technology will help to promote economic development, improve infrastructure and environment, enhance road network, communication system, railway network, waste management and optimize costs of managing public assets in Africa. Read on to learn about the various components of Smart City and infrastructure and their impact in Africa. This includes monitoring and managing of citizens, water supplier, information systems, power plants, civil bodies, and other community services in Africa. According to new study of Navigant Research asserted by Mayuri Patel (2018) published in einfochips (An Arrow Company), observed that the global market for smart city services is expected to reach $225.5 billion within the next decade[2] and Africa is not exempted.

The Smart City views anything physical, electrical and digital (smart city backbone) as its infrastructure (Mohanty et al., 2016). Behind the scene of the smart infrastructure, is the ICT infrastructure, which makes the physical infrastructure "smart" (Mohanty et al., 2016). The availability and performance of the ICT infrastructure are fundamental keys to the construction of smart cities. The overall components of the smart infrastructure may be composed of physical infrastructure, sensors, firmware, software and middleware. The "Middleware" is a specialized software that plays the typical and crucial role of automation and rapid response of the smart infrastructure.
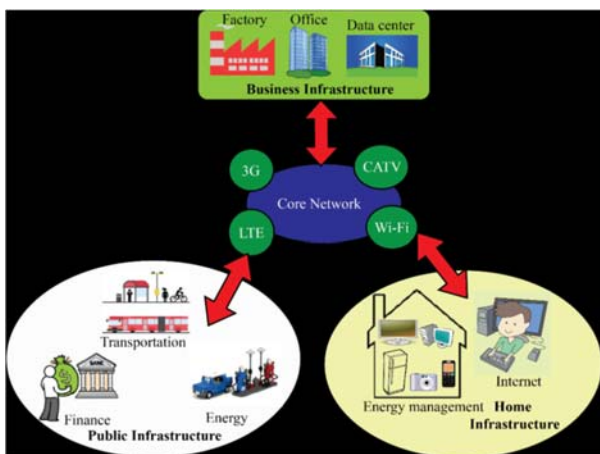
Fig. 3. Smart Infrastructure Depiction.(Mohanty et al., 2016)

3. Smart Transportation

The increase in population, illegal occupancy of vehicles on sidewalks, land acquisition and resettlement issues are one of the biggest challenges related to the planning and implementation of smart transportation. Within Africa there are significant challenges related to the implementation and management of smart transportation. Most notably, Africa has seen rapid smart transportation in other continents, and this trend is expected to continue in Africa. Though, most developed and developing countries have been seen leading the way in the implementation of Intelligent Transport Systems, with the objectives of improving safety, efficiency, and environmental impact of smart transport.

In traditional transportation system there is no consolidation of the various facilities such as railway network, road transportation, airline transportation and water transportation. Each operates independently and posing difficulty to their global usage (Mohanty et al., 2016). However, the Smart Transportation, referred to as Intelligent Transportation System (ITS) incorporates the use of various communication and navigational systems in vehicles, between vehicle (e.g. Car-to-Car) and between vehicles and fixed locations (e.g. Car-to-Infrastructure). We are indebted to the use of ICT and real time data processing for making it possible to have the smart transportation system (STS) and as well to be able to monitor the interactions between these STS entities. Some of the major breakthroughs in smart transportation technology includes but not limited to the use of collision and skidding avoidance sensors to ensure for increased safety in the system (Mohanty et al., 2016).

According to (Menouar et al., 2017), there could be no smart city without a reliable and efficient transportation system. This necessity makes the ITS a key component of any smart city concept. While legacy ITS technologies are deployed worldwide in smart cities, enabling the next generation of ITS relies on effective integration of connected and autonomous vehicles. These two technologies are under wide field testing in many cities around the world. Even though these two emerging technologies are crucial in enabling fully automated transportation systems, there is still a significant need to automate other road and transportation components. To this end, the authors opine that Africa smart cities need smart transport services for movement of people, goods

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[2] Einfochips, An Arrow Company (2018). Understanding the Role of Smart City & its Components in the IoT Era

https://www.einfochips.com/blog/understanding-the-role-of-smart-city-and-its-components-in-the-iot-era/

and services accelerate the growth and development of her region.

Fig. 4. The Smart Transportation System (Mohanty et al., 2016)

4. Smart Energy

Africa is constantly facing energy challenges. Around the world, 1.3 billion people lack access to electricity and more than six hundred million are in sub-Saharan Africa with no electricity. Hence, there is greater energy demand in Africa. For Africa to improve in electricity, Africa needs smart energy for energy market demand and business network. Thus, Smart Energy System as defined by (Lund, Østergaard, Connolly, & Mathiesen, 2017) is " an approach in which smart electricity, thermal and gas grids are combined with storage technologies and coordinated to identify synergies between them in order to achieve an optimal solution for each individual sector as well as for the overall energy system".

In the perspective of Smart City concept, (Mohanty et al., 2016) defines Smart Energy System, as a system that consists of the intelligent integration of decentralized sustainable energy sources, efficient distribution, and optimized power consumption. Smart energy thus consists of three independent building blocks that must be stitched together and effectively communicate with each other to form a unified smart energy system.

A smart energy system consists of new technologies and infrastructures which create new forms of flexibility, primarily in the 'conversion' stage of the energy system. This is achieved by transforming from a simple linear approach in today's energy systems (i.e. fuel to conversion to end-use), to a more interconnected approach. In simple terms, this means combining the electricity, thermal, and transport sectors so that the flexibility across these different areas can compensate for the lack of flexibility from renewable resources such as wind and solar (Lund, Mathiesen, Connolly, & Østergaard, 2014).

The smart energy grids are made to become more robust, more responsive and as well have greater capacity to cater for the increasing demands more efficiently with the utilization of 5G technology (Elvira Galanaki, 2018).

5. Smart Healthcare

The issue of diseases and sicknesses in Africa have brought us to deep thinking about digital and mobile technology as source of creating smart healthcare solutions for people living in Africa. To this end, the smart city trends and evolution which has spread itself in transport, energy, security and infrastructure is sweeping results in healthcare in Africa. A unified smart healthcare system, collecting and sharing of data will usher a new era in tackling modern day healthcare problems in Africa. Thus, the traditional healthcare has become overwhelmed consequent upon the exponential population growth rate in recent years and Africa is not exempted. As a result of this the number of healthcare practitioners has become inadequate to the citizenry's demand (Mohanty et al., 2016). As the resources remained limited and a persistent increase in demand the traditional healthcare need to employ Information and Communication Technology (ICT) so as to become intelligent, efficient and sustainable; this is the trajectory from the traditional to the smart healthcare systems (Mohanty et al., 2016). A typical example of smart healthcare is the Telemedicine system. This breakthrough has made it possible to bridge the healthcare service gap to the distantly and remotely situated citizens as smartphones and devices are being utilized to attain these services (Mohanty et al., 2016),(Elvira Galanaki, 2018).

6. Smart Technology

Today, any technological product or solution that can be hooked to the internet, is interactive in smart city and has a certain degree of intelligence would be classified as smart technology. Smart technology has changed our lives and homes. Hence, (Mohanty et al., 2016) emphasized that smart technology is key to the design, implementation and operations of smart cities.

Presented in the figure below is a synergy of a variety of selected Technologies found in the Smart Cities. A quite a variety of divergent components not limited to; infrastructure, buildings, physical structures, electrical infrastructure, electronics, communication infrastructure, information technology infrastructure, and software, forms the smart cities (Mohanty et al., 2016).

Fig.5. Some Selected Possibilities of Smart Technologies (Mohanty et al., 2016)

7. 5G Impacts on Smart Cities

5G is the short form for Fifth Generation of Wireless Mobile Networks. Date back in the 1980s the First Generation of Mobile Networks were analogue based, capable of carrying voice only. 5G is an enhancement to the 4G, it is 20 times faster and with even a potentiality of up to 100 times faster (Keith Day, 2018). In a recent 5G trial a 2.8Gbps download was consistently achieved. It is no doubt that a lot of strain is being put on the mobile networks, as a result of the exponential growth of data-centric smart devices, as evidently shown according to (Keith Day, 2018) in 2016 alone, the global annual mobile traffic hit 7.2 Exabytes per month (One Exabyte is equivalent to one billion Gigabytes). The utilization of radio spectrum is the science behind 5G's increased speed and network capacity. Higher frequency bands ranging from 3.5GHz to 26GHz are utilized by 5G to attain faster and less cluttered connectivity(Keith Day, 2018).

In a report by (Elvira Galanaki, 2018) it is indicated that 5G networks are developed to tremendously improve on latency (end-to-end transmission delay measure) of as low as 1millisecond. In comparison to the 4G networks at 40-60 milliseconds, this is a significant improvement. While the predecessors of 5G that is, 3G and 4G are focused on connectivity via personal devices, 5G is going to integrate with infrastructure, buildings, appliances,

vehicles (components of the smart city) and products to deliver unprecedented benefits for citizens in the areas of transport, healthcare, energy, commerce and leisure (Elvira Galanaki, 2018).

The 5G Wireless Technology has impacted on virtually every aspect of the Smart City concept. However, this review concentrates on four key sectors, namely: Energy, Healthcare, Transport, and lastly Retail and Commerce.

Fig. 6. Smart City Concept in 5G (Phan & Shoaib, 2017)

7.1   Energy – One of the principal cardinals of 5G is to leverage on its technology to improve on the traditional infrastructure (Elvira Galanaki, 2018). So, with the embedding of low-power, low-cost 5G sensors within the grid, the system becomes intelligent to detect and respond to increase in demand caused by a certain activity, for example the mass charging of electric vehicles. Hence a reduction in the chances of blackouts and low voltages that have severe consequences on sensitive equipment (Elvira Galanaki, 2018).

5G will enable very low-cost connections between the devices and monitoring of these devices will be efficient such that to manage energy needs properly. The important and the best part is that it will help in balancing the load of the cities in a way like reducing the electricity peaks depending upon the situation of the usage and hence reducing the cost of the energy (Phan & Shoaib, 2017).

7.2   Healthcare – With their responsiveness and speed, 5G enabled technologies according to (Elvira Galanaki, 2018) will set grounds for improvements in telecare, telehealth imaging and data collection, aggregation and as well as analysis. With its reliability and secure connectivity 5G Technology will pave way for

the wide scale adoption of quite a number of digital healthcare services ranging from health video conferencing, GP consultation to digital health monitoring with the aid of smartphones or other smart devices, as highlighted by (Elvira Galanaki, 2018). More breakthroughs in this area is the use of Ambulance drones. A drone unveiled in 2014 offered the possibility of providing much quicker care to heart attack victims by coming equipped with a defibrillator (Michelle Starr, 2017) and as a result of this quicker response time to cardiac patients the chances of their survival has significantly increase form 8% to 80%.

7.3   Transport – With the exponential increase in the cities' population due to urban to city migration day by day both the cities' transport infrastructures and commuters are posed with strain and pressures. However, by leveraging on the deployment of 5G technology into the city's transport design and infrastructure traffic and rail management systems can be upgraded to cope more efficiently with the increased demand (Elvira Galanaki, 2018).

A great deal of traffic decongestion have been attained by both transport services and the councils according to (Elvira Galanaki, 2018) with the introduction of low-power and low-cost 5G sensors in key public transport infrastructure like the railway lines and traffic lights.

The advent of 5G informed the utilization massive Machine Type Communication (mMTC) which enables cities, transportation and infrastructure to transmit real-time data for attainment of improved maintenance and greater operational efficiency (Ericsson, n.d.).

7.4   Retail & Commerce – Hitherto the retail sector has confined the use of mobile technology to track, target and entice customers into shops using discounts and advertorials (Elvira Galanaki, 2018). However, the emergence of 5G with its higher speeds and improved mobile connectivity the retailers and commercial businesses understanding of their customers shopping patterns will be turnaround (Elvira Galanaki, 2018).

7.5   Industry 4.0 and the Smart City

Credit is due to the digitization of manufacturing, which has significantly transformed the way products are produced (Marr, 2018). Therefore, according to (Marr, 2018) because of this transition it is so compelling to be called Industry 4.0 to represent the fourth revolution that has taken place in manufacturing.

The industrial revolution trends are: First revolution which witnessed mechanization using water and steam power, the second revolution came with mass production and assembly lines using electricity, the third revolution (Industry 3.0) witnessed the introduction of computers and the fourth revolution (Industry 4.0) takes from where Industry 3.0 stops and leverage on adoption of computers and automation with enhancements through the use of smart autonomous systems driven by data and machine learning (Marr, 2018).

In the words of (Marr, 2018) " Now, and into the future as Industry 4.0 unfolds, computers are connected and communicate with one another to ultimately make decisions without human involvement. A combination of cyber-physical systems, the Internet of Things and the Internet of Systems make Industry 4.0 possible and the smart factory a reality. As a result of the support of smart machines that keep getting smarter as they get access to more data, our factories will become more efficient and productive and less wasteful. Ultimately, it's the network of these machines that are digitally connected with one another and create and share information that results in the true power of Industry 4.0"

Fig. 7. Pictorial depiction of Industry 4.0 (Marr, 2018).

7.6   Internet of Things and The Big Data

7.6.1   Internet of Things

It is such a trivial task to precisely define Internet of Things. According to (Techopedia, 2018) The Internet of Things (IoT) is a computing concept that describes the idea of everyday physical objects being connected to the Internet and being able to identify themselves to other devices

From another view point, Internet of Things as defined by (Gartner, n.d.), is the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment.

Talking about being connected, a lot of people have limited their thinking in terms of computers, tablets and smartphones, while IoT is divergent in its view, it sees it as a world where just about anything can be connected and communicate in an intelligent manner (Techopedia, 2018). This is where the smart city comes in. So, consequence upon this development the world is transcending to one big information system.

The use of Data and Technologies is the general platform under which the smart city operates in order to improve the lives and businesses of the citizenry dwelling in it. A search to these technologies converges to one: The Internet of Things – The Smart City Technology (Nick, 2018). The registered successes of the smart city initiative be it improvement in pollution level or vehicular traffic condition is credited to the IoT which is the Technology behind the scene, as (Nick, 2018) further explained.

7.6.2 The Big Data

As defined by (Gartner, 2018) is "high-volume, high-velocity and/or high-variety information assets that demand cost-effective, innovative forms of information processing that enable enhanced insight, decision making, and process automation".

Big data technology is one of the critical building blocks of Smart City, perhaps it is seen as having the potential of being the foundation of making the smart city (CIOReview, 2018). The following were presented by (CIOReview, 2018) as some of the ways big data has been utilized to form the foundation of Smart City:

i.   **Security:** Citizens' safety is one of the top priorities in a city in any scenario. In any case of troubles, predictive analysis helps to handle the situation by recognizing when and where crimes are likely to happen by the study of historical and geographical data.

ii. **Planning:** The sensors installed in the city help to have a clear picture of what is lacking in the city and how to improve it. A city needs mapping infrastructure to pinpoint where development is needed to become a smart one.

iii. **Transport:** Traffic problem is one of the transportation problems a city has. This problem can be managed by big data by analyzing data, collected from transport authorities. Big data tools study about the patterns causing the traffic congestion. It helps transport authorities with an intelligent way of reducing the problem.

iv. **Future proofing:** Urbanization makes a city smarter. Automation should be used to handle traffic routine with real-time management and monitoring. Data collected from various sources should be used with high efficiency and less wastage.

8. Discussions

Recently Africa's urban centers (cities) are highly in a mood swing towards utilization of advanced technology and data (Meko, 2016). This development has set the ground for the attainment of smartness. Therefore, we can say that Africa's cities are embracing the Smart City concept, as application of powerful analytic programs via the use of Smartphones is causing revolution in consumer and utility service provisioning.

As the Smart City and Smart Utility are in their growing research phase, surely Africa's cities will not be left behind. In order not to be left behind Africa's cities need to strategize, do a lot of thinking and planning along their counterpart of the developed world. According to (Meko, 2016) in order to infuse smart city and utility thinking into the planning process, a number of key items need to be considered in the African context:

a) Advancing high speed telecommunications networks and infrastructure;
b) The real assimilation of smart-oriented thinking into policy, master planning and delivery;
c) The need for Africa-centric baseline data in key markets; and
d) The realization of pilot sites that could guide the establishment of smart cities and the uptake of smart utility.

Currently it is evident that opportunities are seen in South Africa – specifically Johannesburg and Cape Town. Kenya – Nairobi, and then followed by other hubs such as Nigeria, Egypt, Rwanda and Ghana these are countries where technology advances are on the rise capable of supporting smart innovative districts (Meko, 2016).

Fig. 8. Africa A Playground of the Future Through Smart Cities (Meko, 2016).

9. Summary

The Smart City Technology has leveraged on all the current trending technologies such as: Cloud Computing, Green Computing, Internet of Things, Big Data, 5G Networks etc. and the underlying Information and Communication Technologies consolidating and harnessing them all to attain its existence and functionality.

10.   Conclusion

With the attainment of technological advancement in virtually all aspect of human endeavor, it is certain that this trending concept 'Smart City' will be widely spread and adopted in African countries, and at large in global scale. This is so because Smart City Technology is targeted at improving the quality of life in the cities, and as well as helping the councils and city governments provide improved, and sustainable services and safeguard their infrastructure (Nick, 2018).

Smart cities in Africa are characterized by technological lag when compare to other continents, so the transition to smart city with technological advances is advisable. It will allow digital ecosystem not only within the cities, but also to enhances liveability, workability, economic development, innovative businesses, healthcare and sustainable infrastructure in Africa.

References

Caragliu, A., Del Bo, C., & Nijkamp, P. (2009). Smart Cities in Europe_Caragliu_JOT. *Journal of Urban Technology*. https://doi.org/10.1080/10630732.2011.601117

CIOReview. (2018). How Big Data is Helping in Building a Smart City.

Elvira Galanaki. (2018). The value of 5G for cities and communities. In *O2*.

Ericsson. (n.d.). Smart Vehicles and Transportation Ericson.

Gartner. (n.d.). Internet of Things.

Gartner. (2018). Big Data.

Harrison, C., Eckman, B., Hamilton, R., Hartswick, P., Kalagnanam, J., Paraszczak, J., & Williams, P. (2010). Foundations for Smarter Cities. *IBM Journal of Research and Development*. https://doi.org/10.1147/JRD.2010.2048257

Keith Day. (2018). What is 5G and what does it mean for smart cities? | Telensa.

Lund, H., Mathiesen, B. V., Connolly, D., & Østergaard, P. A. (2014). Renewable energy systems - A smart energy systems approach to the choice and modelling of 100 % renewable solutions. *Chemical Engineering Transactions*. https://doi.org/10.3303/CET1439001

Lund, H., Østergaard, P. A., Connolly, D., & Mathiesen, B. V. (2017). Smart energy and smart energy systems. *Energy*. https://doi.org/10.1016/j.energy.2017.05.123

Marr, B. (2018, September). What is Industry 4.0? Here's A Super Easy Explanation For Anyone. *Forbes*.

Meko, W. (2016). Africa: A Playground of the Future through Smart Cities. *IT NEWS AFRICA MAGAZINE*.

Menouar, H., Guvenc, I., Akkaya, K., Uluagac, A. S., Kadri, A., & Tuncer, A. (2017). UAV-enabled intelligent transportation systems for the smart city: Applications and challenges. *IEEE Communications Magazine*. https://doi.org/10.1109/MCOM.2017.1600238CM

Michelle Starr. (2017). Ambulance drones are faster than emergency services.

Mohanty, S. P., Choppali, U., & Kougianos, E. (2016). Everything you wanted to know about smart cities: The Internet of things is the backbone. *IEEE Consumer Electronics Magazine*, *5*(3), 60–70. https://doi.org/10.1109/MCE.2016.2556879

Nick, I. (2018). Smart City Technology: It's all about the Internet of Things.

Phan, A., & Shoaib, T. Q. (2017). 5G Impacts on Smart City 2030. *ResearchGate*, (March), 1–13.

Techopedia. (2018). What does Internet of Things (IoT) mean?