

Big Data-IoE Relationships and the Future of Smart Cities

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Abstract—Urbanization has become a serious problem across most countries. Many developing countries like China and India are identified as suffering from the rise of urbanization over the past few years. The development of smart cities is an effective solution to major problems within most cities today. Internet of Everything (IoE) is identified as a critical solution needed in developing smart cities of the future. The Internet of Everything is identified as the networked connection of data, things, processes, and people. This means that IoT devices are a crucial element of the IoE but big data plays a key role in storing and processing those information for insight extraction. The study adopts a systematic review methodology. The selected articles are reviewed and analyzed to provide answers to the objectives selected. Each of these concepts is guided by the multidisciplinary theoretical framework. The Framework identifies that the components within a smart city should be interconnected, as identified in the pillars of the IoE.

Index Terms—Big Data, IoE, IoT, smart cities, network intelligence.

I. INTRODUCTION

Smart cities have become an interesting new concept adopted in solving most of the challenges experienced across cities [1]. Smart cities are modern urban centers that are interconnected through a system of sensors and devices that automate most processes. The development of smart cities has been attributed to solving some of the key challenges experienced within most communities today [2]. Smart cities are developed to address city challenges, interact with the community, and reduce most challenges identified across major cities struggling with urbanization. The relationship between big data and IoE is a crucial technological innovation that can contribute to revolutionizing smart cities in many dimensions. “IoE is the networked connection of people, process, data, and things” [3]. The article shows that IoE continues to develop opportunities for individual communities and the organizations within these communities. Introducing

network intelligence within the communities promotes the ability to develop smarter decisions and affect the community significantly. Smart cities are made more efficient because of the interconnections and integrations within them [4]. The introduction of intelligence networks is, therefore, crucial in promoting success within these cities.



Figure 1. Smart city investment by 2023 [5]

As IoT device usage increases in the world (Figure 2), IoE is becoming a crucial technological development in ensuring that significant developments have been achieved within these cities [6]. There is, however, a gap in finding all of the applications that IoE is expected to introduce to smart cities. Smart city developers must develop their cities with the understanding of the impact that IoE will introduce [5, 6]. The future of more effective smart cities depends on the success of IoE.

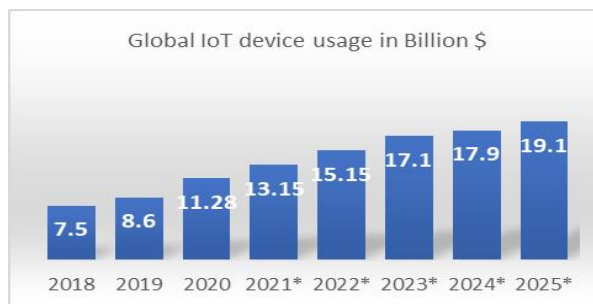


Figure 2. Global IoT device growth in Billion \$. *Future years

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II. RESEARCH OBJECTIVES

Research objective is defining the way we plan and execute our research and our focus areas. The steps are:

- a) To examine the state of IoE technologies and their applications.
- b) To identify the key challenges and problems expected to impact smart city developments.
- c) To identify the impact that IoE systems have on smart city development.
- d) To recommend specific actions that various stakeholders should implement in promoting the benefits of IoE technologies in smart cities.

III. LITERATURE REVIEW

The internet has revolutionized many services across the world today. Miraz et al. (2015) identify that the internet has endless opportunities that need to be identified [7]. The development of technologies such as the IoE and IoT is shown to be the beginning. The article also identifies the need for scholars to continue analyzing some of the impacts that IoE could have on global success. Organizations are also advised to focus their research on the Internet of Everything systems and be ready for the future that these technologies will create.

The internet is becoming increasingly popular due to increased services and products introduced daily. The development of Internet of Things (IoT) devices has been a major factor in the way many technologies are becoming connected to the Internet [7, 8]. More devices are also being developed to access and use the interconnectedness introduced by the internet. Therefore, Jara et al. (2011) support that the Internet of Everything is developed to promote seamless and autonomous coordination between the various sensors and devices [9]. IoE also ensures seamless coordination between people, processes, and data.

One of the key potentials of IoE is in revolutionizing the smart grid. Zielinski (2015) identified the impact that IoE has on smart grid systems. Smart grid systems are a significant technology contributing to extensive power-saving costs. Zielinski [11] supports that developing smart grid systems increases the data within these systems. The massive amounts of data must be analyzed to ensure that the operations in the smart grid are effectively controlled. Zielinski also identifies that IoE ensures that the coordination between the systems, the data collected, and the stakeholders has been managed [11].

Smart cities of the future are considered a revolutionary step in solving most of the challenges experienced in today's cities. Batty et al. [12] identify that more cities are introducing systems necessary to improve their operations. The automation of critical processes within the cities has helped solve several challenges within these cities. However, Batty et al. identify that future designs should focus on equity and the need to improve the quality of life for residents within these cities. Batty et al. address

the need for future smart cities to offer better mobility and information analysis [12]. This development will significantly influence the success that smart cities can achieve.

Yin et al. [13] addresses that urbanization is creating a huge problem within most cities. The article finds that China's urbanization has resulted in the development of megacities. These cities have introduced several challenges impacting the livelihoods of people. Yin et al., therefore, emphasize the need for smart city developments to focus on key domains needed to promote their success [13]. These domains include governance, technical infrastructure, the applications domain, and citizens [7]. Addressing each of these domains is shown to be critical in building a successful city.

The focus on IoE becomes a crucial element because of the applications it introduces towards the development of future smart cities. IoE is expected to offer intelligence and value to how smart city operations are controlled. The focus on processes is necessary to ensure that smart city functions are effectively achieved [2]. There is, however, a significant gap in the literature addressing the application of IoE in smart cities. Addressing this gap will help developers implement smart city technologies with the help of IoE effectively. The solutions associated with the smart cities will, therefore, be improved through the IoE implementation.

IV. BIG DATA-IOE RELATIONSHIPS

How the IoE and Big Data are related in a smart city project may be a subject of interest. IoE is an example of IoT technology, and in terms of big data, the data and machine logs generated by IoT devices are valuable structured and unstructured big data [4]. This is so that businesses may obtain more specific information about their devices and how they are used as it is connected to a physical item. If we use a hypothetical "smart home" in a smart city as an example, complete with devices and technology that collect this data, some of the things that can be tracked include:

- a) The inside temperature and humidity.
- b) The internal air quality of the home.
- c) Household energy use across all gadgets.
- d) Levels of activity and behavioral patterns.
- e) Level of usage, alerts, and future recommendations.

Because it is automatically gathered and processed, less data is wasted, making all of this information valuable to businesses. Additionally, a lot of IoT platforms collect data streams using machine learning. These big data sets will then be correlated and analyzed together. IoE continuously gathers and processes data. This translates to quicker and frequently more accurate information gathering [13, 14]. Utilizing all the data gathered results in more beneficial, actionable insights

for businesses. The resultant higher ROI (return on investment) can be a result of this and is very beneficial to smart city projects. Figure 3 shows a Big Data-IoE relationship below in detail.

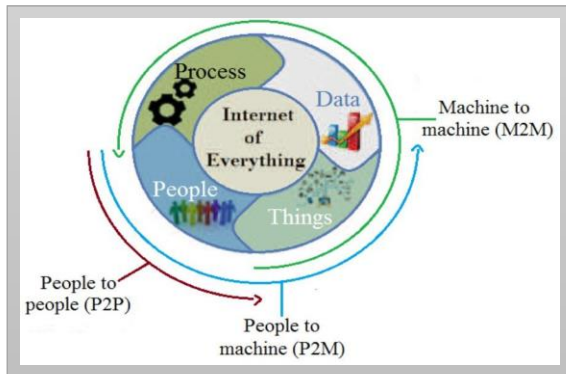


Figure 3. Big Data-IoE Ecosystem. Adapted from [3]

V. MEHODOLOGY

Theoretical Framework : Pena et al. [15] identify that the Internet of Everything is centered around four main pillars. These pillars include the devices, the people, and the objects available. Jara et al. [7] also describes processes to be a crucial element within the IoE. The research below will employ a multidisciplinary approach that identifies how various concepts relate to and impact each other. The framework identifies the impact that IoE will have on the future of smart city development. Future smart cities will be based on the Internet of Everything as identified from the theoretical framework shown. The central component in the theoretical framework is the IoE components. These components are identified to work and interrelate with the development of smart cities. Smart cities are developed to house various individuals [13, 14].

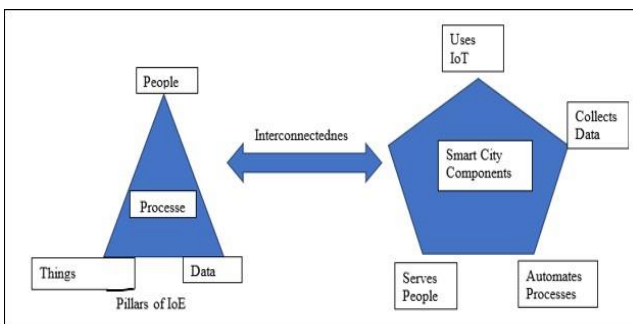


Figure 4. Multidisciplinary Theoretical Framework in Smart City projects

The technologies within smart cities are aimed at automating various projects. Automating various processes ensures that smart city developments have become more efficient. The sensors are implemented across various devices in the smart cities [2]. The sensors can collect data, another crucial element, and foundation of the IoE. Figure 4 below finds the theoretical framework for the study and all the components involved.

VI. DATA COLLECTION, PROCESSING AND ANALYSIS

A systematic review was employed to obtain relevant data for this research. The methodology followed a systematic review approach. Journal articles published in the past five years were collected to inform the theoretical framework developed. Various databases and journals were used to acquire the data. The keywords used in researching these studies include IoE, smart city development, smart city challenges, Internet of Everything, and Internet of Things. Around 15 studies were obtained from the search across the selected databases. The inclusion criteria focused on studies that included at least three identified keywords. Studies focused on the impact of IoE in smart city development were used. The data was relevant in answering the objectives identified for the study. Figure 5 below identifies the phases adopted to obtain the relevant studies and collect relevant information from the information in the selected studies.

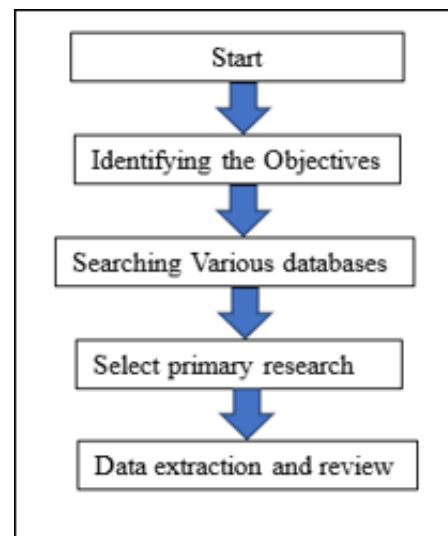


Figure 5. Stages of Research Process

The study collected qualitative data from the various studies obtained. The qualitative data was then reviewed using the thematic process. This process aims to identify common themes within the studies collected [16]. Some of the challenges identified within IoE systems in smart city developments are also identified. This information is crucial in showcasing some of the actions that smart city developers should consider ensuring that the IoE is successful in their city developments. Implementing these factors will help promote future smart cities guided by the Internet of Everything.

VII. RESULTS AND DISCUSSION

The four objectives identified were used to inform the results and discussion section as identified below. The

objectives are answered systematically based on the data collected.

A. To Examine the state of IoEs and their Applications

The Internet of Everything is a growing factor that will revolutionize the world in the next few years. The rise and popularity associated with the internet have significantly contributed to the rise of IoE across various developments. Jara et al. [8] identify that the Internet of Everything can promote automation within smart city developments. IoE can promote more effective automation because it considers people and processes. People and processes are crucial to developing the IoE [17]. This makes IoE an effective tool for developing better automated smart cities.

B. To Identify key challenges and problems expected to impact Smart City developments.

Jara et al. [8] identifies that IoE implementation in smart city development will be affected by several factors. The main factor that will impact the success associated with IoE is the connectivity of the devices. Connectivity relies on the internet, which enables all the components to be connected [18].

When developing smart city developments, the network must be well-developed. The next challenge associated with IoE and IoT developments is security concerns. Security has been identified as a critical factor in the success achieved by IoE in smart city developments [19]. The cities of the future are required to address security concerns effectively. IoE impacts societies through the interconnectedness of people [20]. Security concerns introduce a significant problem to how effective the cities will be. This challenge should, therefore, be addressed through effective and reliable technologies available. Figure 6 below summarizes these challenges and their impact on IoE.

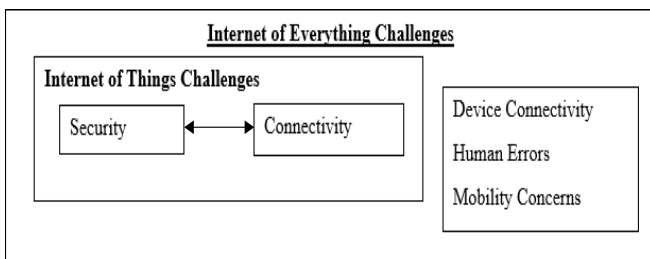


Figure 6. Challenges of IoE

C. To identify impact that IoE systems have on Smart City development.

Zielinski [9] found that the Internet of Everything can be a crucial element in developing smart cities of the future. The study identifies that the smart grid is one of the technologies crucial to developing smart cities. Smart grids can solve societal challenges by focusing on the automation of services within the community. IoE

emphasizes sensors and devices to be connected to the internet [18]. The development of smart cities is therefore required to focus on IoT devices, which will resolve most of the challenges within many cities. The interconnection of these devices is also recommended to be an effective addition to the people within these regions. Zielinski [9] describes that introducing people into the equation helps eliminate the redundancies achieved during development.

D. To recommend specific actions that various stakeholders need to implement promoting benefits of IoE.

Smart city developers must understand the applications and impact that IoE has on smart city developments. Future smart cities should consider the importance of the Internet and the interconnectedness of all elements within the city [19]. Connecting the various elements will help eradicate most challenges in today's smart cities (see Table 1). Security is a relevant concern associated with IoT technologies. IoE integration into smart city developments should highly consider the risks attributed to these developments. The lack of proper preparation risks the success that future smart cities can achieve [9, 20]. The security concern should, therefore, be a critical factor when developing smart cities.

Table 1. IoT and Big data impact on Smart city factors

Smart City Problems	IoT Technology	Big Data Technology
Transportation	Yes	Yes
Healthcare	Yes	Yes
Traffic Control	Yes	No
Banking	Yes	Yes
Waste Management	Yes	Yes
Education	Yes	No
Predictive Analytics	Yes	Yes
Data Analysis	No	Yes
Reporting	No	Yes

Research also shows that smart cities are the future for most developments. The amount of data expected within the next few years is massive (see Figure 7). This data should be considered when developing a smart city. Future smart cities will include massive amounts of data that must be analyzed in real-time [21]. The analysis of this data requires that developers have invested in big data and AI technologies, and data analytics technologies [22]. These technologies will be crucial in promoting reliable smart city developments that serve the needs of the people.

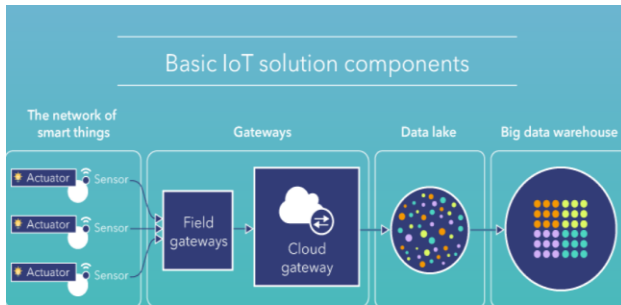


Figure 7. IoT and Big Data Components in Smart City [22]

As technology evolves, the complexities of smart city initiatives are going to arise in operational and data management perspective [23]. However, the timely and efficient use of IoT and bigdata technology will act as catalysts in future projects to address these issues. In the long run, technological push is the greatest method to overcome smart city obstacles.

VIII. CONCLUSION AND RECOMMENDATIONS

Considering global rise in population and facilities, smart cities are the future for sustainability. The paper adopts a multidisciplinary approach that showcases the way concepts on the Internet of Everything can be implemented towards developing smart cities of the future. Big data plays a very crucial role with IoE for data analysis, machine learning, and future predictions, improvements, and recommendations. Smart city developments have become a crucial new technology needed to address most of the challenges experienced in today's cities. The systematic review methodology identified data from different studies, which were then analyzed to address the objectives identified in the study. The implementation of reliable and relevant technologies during the development of smart cities is identified to be an effective measure needed in smart city developments. The developers are also advised to consider some of the challenges that could be achieved. These actions will promote the development of future reliable and effective smart cities.

The research has some limitations that can help guide future research. The main limitation identified was that the number of studies obtained for the critical review was very small. The research is, therefore, limited, as showcased by the few studies used in the critical review. Future research studies should obtain a larger sample for the critical review. More studies are crucial in ensuring a deeper review has been conducted and that more information has been obtained. Future studies can obtain a larger scope by focusing on more effective inclusion criteria, which will also help in identifying more results from the study.

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