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A Review on Integration of IoT as an Approach for Energy Saving in Smart Sustainable Cities

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Abstract: Rapid urbanization has been happening around the world, leading to many challenges and difficulties in infrastructure, communication network, transportation, environmental and organizational problems. Proper and responsible management of urban resources plays a significant role in sustainable development. Smart sustainable cities use ICTs (information and communication technologies) to improve quality of life, efficiency of urban operation and services. The latest advancement in communication, technology, data management, and IoT (Internet of Things) provide a tremendous role for practical implementations and adoption of devices and entities. Smart sustainable cities can be intellectualized as an innovative approach of controlling urban resources and valuable components based on the latest advancement in information and communication technology. Our study focuses on reviewing and discussing the literature that states the vital components of IoT associated with smart sustainable cities in general and specifically with green energy.

Key words: Devices and sensors, smart sustainable cities and green energy.

1. Introduction

Recently, rapid urbanization has been happening around the world by vast number of citizens coming toward cities. Based on the world urbanization prospects publicized via United Nations Department of Economic and Social Affairs around 55% of world population lives in cities and it is predicted to reach 70% by 2050 [1], even though cities drive the country's economy and contribute greater percentage to the GDP (Gross Domestic Product) by providing occupation and expand per capita spending. Local governments are experiencing enormous pressure to provide and sustain the smallest possible provisions needed aimed at everyday routine life. Rapid urbanization and rising populations lead to many challenges and difficulties in infrastructure, communication network, transportation, pollution, and organizational problems [2]. Significantly, proper and responsible management of urban resources is an essential key factor for sustainable development in rapidly urbanizing regions [3]. A smart city can be intellectualized as an innovative approach of controlling urban resources and valuable components based on the latest advancement in ICT (information and communication technology) [4].

At the end of the 1990s the perception of smart cities was released and became increasingly popular and appealing. In the last two decades, many definitions of smart cities were discussed and suggested by individuals and organizations. The BSI (British Standards Institution) defined the smart cities as "an effective integration of physical, digital and human systems in the built environment to deliver a sustainable, prosperous and inclusive future for its citizens" [5]. In addition, The ITU-T (International Telecommunication Union Telecommunication) Standardization Sector Focus Group on Smart Sustainable Cities reviewed around 100 published definitions of smart cities as well as revealed that "smart sustainable city is an innovative city that uses ICTs (information and communication

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technologies) 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" [6].

Significantly, the Technical Management Board of ISO (TMB) collaborates through completely key standard bodies for progressing a public definition as "smart city is one that dramatically increases the pace at which it improves its social economic and environmental (sustainability) outcomes, responding to challenges by fundamentally improving how it engages society, how it applies collaborative leadership, how it works across disciplines and city systems, and how it uses data information and modern technologies in order to provide better services and quality of life to residents without unfair disadvantage of others or degradation of the natural environment" [7]. However, the definition of smart cities is suggested to be a moving target based on latest advancement in ICT (information and communication technology), since what was smart in previous years is now predominantly a part of the consistent infrastructure [8].

The rest of the paper is organized as follows: Section 2 elaborates on civil engineering thrift in a smart city world. In Section 3, the study presents an analysis of smart sustainable city conceptual background. In Section 4, the study provides a generic smart city architecture, which confirms with many proposed architectures. Section 5 elaborates the methodology adopted to perform this study. In Section 6, we highlighted the importance of devices and sensors for IoT (Internet of Things) based services. In Section 7, discussion of targeted papers and their challenges, open issues, and limitations are identified. Finally, the conclusions are presented in Section 8.

2. Civil Engineering Thrift in a Smart City World

Civil engineering is defined with the design, building, and conservation of the physical and natural built environment in and around cities. Civil engineers work to develop and preserve the environment to develop the superiority of existence on behalf of present as well as forthcoming creations. In essence, civil buildings are essential for everything from food and water distribution to good sanitation and dependable transportation. In isolation, digital technologies have little relevance. They bring value by making it easier to handle issues in the civil engineering field.

According to evidence from the literature and interviews, digital technology gives civil engineers with two main opportunity groupings. First, they want to operate more efficiently, doing what they already do quicker and cheaper; second, they want to work more effectively, providing more value to their solutions. Nowadays, the tale of digital innovation in the civil engineering profession is one of incremental improvement.

Civil engineering has made notable incremental advancements aimed at increasing output efficiency. However, regardless of how enthusiastically they are promoted in the future, it is likely that continuing the "faster and cheaper" mentality we have experienced would result in diminishing results at best, and at worst will detract from the possibilities of more dramatic and beneficial transformation. Many components are missing in civil engineering. There is no agreed picture of what "better" innovation may look like, or why it is strategic. Engineers lack particular learning direction, corporations lack suitable frameworks, and the profession is unsure how to fully commercialize the promise of digital innovation [9].

On the horizon, threats to the profession are multiplying. Business models are becoming obsolete. New sorts of competition appear to be more inventive and agile. Similarly, because of their own digital experiences, citizens' expectations of infrastructure continue to rise. Fear of a sudden, massive upheaval is growing, but it appears too far away to catalyze change. There is no evidence that civil engineers will disappear in the future, but there are indicators that the number of

professionals, scope of work, and market share may all decrease. On its current trajectory, civil engineering can only hope to thrive in the age of smart cities [10].

3. Smart Sustainable City Conceptual Background

The perception of smart sustainable city has gained global consideration so implying methodology to the argues of urban sustainability based on advances on internet technology and communications [11]. Corresponding to the World Commission on Environment and Development, sustainability aims to achieve three essential aspects including social, environmental, and economic sustainability, where the metabolism of cities and consumption of urban energy resources and materials should not exceed natural provided resources [12]. Consequently, the perception of smart sustainable cities proposed by academics and researchers as a response to global urbanization. Comprehensively, a smart sustainable city was defined as a pioneering city which utilized recent advances of technology as well as internet for developing property of life, operations and services for urban citizens and future generations. Chang et al., declare that sustainable should be combined with smart to perform the dynamic response to urban challenges and achieve the desired outcomes and improvement for present inhabitants [13].

Yigitcanlar et al. report that cities couldn't transform dramatically into smart without being sustainable. Nevertheless, cities should be smart in all aspects, not just focusing on some smart solution for certain urban challenges [14]. Accordingly, ICT plays an essential role during planning, operating and management of urban system contributing and leading to sustainability [15]. The European Commission and the United Nations debated that newfangled holistic methodologies of urban scheduling and expansion of infrastructural, effective, purposeful forms and models of cities are an urgent need to mainstream pioneering results and complicated procedures based on ICT to overcome the raising challenges of urbanization in contemporary cities [16, 17].

Since the involvement of technological environment, the discipline of smart cities constitutes interdisciplinary research area. The most recent advances in communication, technology, data management, and Internet of Things (IoT) provide a tremendous role for practical implementations and adoption of devices and entities. Essentially, IoT consists of four vital components including devices and sensors, connectivity, data storage and processing, and interface. IoT applications in smart sustainable cities interconnected physical devices and infrastructures with different types of sensors through an embedded software with reliable connectivity infrastructure to create dynamic automated system to control, monitor, and manage all available resources and response to intelligence decision making in anytime and anywhere. Connectivity infrastructure is the main backbone of IoT applications, which is mainly composed of communication architectures based on wireless or wire networks or in most situations based on heterogeneous network.

4. An Overview of IoT Architectures

Today's requirements for supervising and controlling various plans in companies need the use of an IoT (Internet of Things) platform capable of integrating heterogeneous parts offered by many manufacturers and utilizing various protocols, data formats, and communication technologies. It is preferable to have a universal IoT platform that can be utilized for several devices without relying on a single vendor. On the market, there are multiple proprietary business IoT systems that allow for the connection of various devices as well as the collection, storage, and analysis of their data. These platforms are often delivered via the SaaS model. Nevertheless, if the establishment or association previously has its own cloud and network infrastructure, another motivating opportunity is to utilize about of the obtainable free and

open-source IoT stands and schemes and install them unswervingly on such substructure, sidestepping the custom of exterior cloud explanations [18].

The vast amount of collecting and delivering data based IoT require an efficient and sufficient storage capacity to create ubiquitous transmission of IoT [19]. Commonly, the most relevant communication architectures utilized in smart sustainable cities can be summarized into three main technologies; LPWAN (low-power wide-area network) which is designed to connect devices based low power batteries for applications requires low transmitted data such as LTE-M (long-term evolution machine), NB (narrowband)-IoT and LoRa-IoT (long range IoT) [20, 21]. Currently, the 5G (fifth generation) provides very high-rate bandwidth with low latency supporting IoT applications in smart sustainable cities [22]. On the other hand, proper utilization and implementation of IoT are significantly dependent on the quality of created infrastructure which requires initial investment [23].

Subsequently, indicators and frameworks were developed to evaluate smart cities and assist municipalities to set targets and perform continuous monitoring for performance [24]. Furthermore, IoT applications have the potential to assist management of natural resources, energy consumption, public transportation and environmental protection and impact [25]. Therefore, smart sustainable cities aim to implement the SDGs (Sustainable Development Goals) including smart transport and mobility; smart society and people; smart economy and innovation, smart energy, and environment [26]. This study focuses on reviewing and discussing the literature that states one of the vital components of IoT which is the devices and sensors associated with smart sustainable cities in general and specifically with green energy.

5. Methodology

As mentioned before, IoT involves four necessary modules which are devices and sensors, connectivity, data storage and processing, and interface. This section presents a synopsis of the research that has been done in developing sensors and gadgets related to green energy and smart sustainable cities in general. With an emphasis on the most important discoveries, contributions, and developments in the subject, this survey seeks to give a thoroughgoing summary of the state of the research now. We want to find areas of interest and gaps in the current literature that need to be filled to build and implement smart, sustainable cities. By using this poll as a starting point for our thorough systematic evaluation, we can synthesize and rigorously analyze the results.

In a comprehensive literature analysis, published papers that address and debate the research issue of devices and sensors linked with smart sustainable cities in general and with green energy in particular are retrieved, mapped, aggregated, configured, and critically evaluated. Google Scholar was chosen from the available collection of scholarly research databases because of its extensive coverage of thirty-two excellent, peer-reviewed studies that are rigorously regulated and pertain to the subject matter. This study developed a broad-based search string covering the various topics of the study and the associated links to retrieve the scholarly literature from academic publishers, professional societies, online repositories, universities, and other websites. This online platform offers a straightforward method for conducting a broad search for scholarly literature across many disciplines and sources.

However, the search string included: “devices and sensors” & “IoT” & “smart sustainable cities” & “green energy”. These were utilized to search for contradictions of the title, abstract, and keywords of articles to produce initial insights. The final database, which included thirty-two documents in total, was considered reliable when conducting a systematic review [27]. The reviewed papers were published in foremost journals and conferences in urban planning, sustainable urban development, ICTs (information and

communication technologies), IT (Internet technology), energy generation, storage, consumption and SSCs (smart sustainable cities). Among these outlets were "Environmental Science and Ecotechnology", "Sustainable Development Goals, Climate Change, and Digitalization", "Energy Reports", "Proceedings of International Conference on Data Science and Applications", "Cities", "Sustainable Interdependent Networks II", "IoT & Sustainability: Practice, Policy and Promise", "Smart Cities—Opportunities and Challenges" and "Urban Informatics". These outlets highlighted the research's relevance and significance in furthering the understanding and implementation of devices and sensors integrated in IoT technologies associated with smart sustainable cities in general and specifically with green energy.

The literature search was handled in the beginning of June 2023 and resumed 32 articles encompassing 2016 to 2023. The launching year was chosen since it demonstrated that ITU helped launch the World Smart City online community, that is further part of the build-up to the first World Smart City Forum, to be arranged in Singapore on 13 July 2016. Moreover, in this year (i.e., 2016) ITU worked to ensure a coordinated United Nations contribution to the work of Habitat III, the UN Conference on Housing and Sustainable Urban Development to be held in Quito, Ecuador, from 17 to 20 October 2016. The full period, 2016-2023, gains the comprehensive nature of the topic of smart sustainable cities from the evaluation of IoT expertise regarding devices, sensors, and green energy.

6. Importance of Devices and Sensors for IoT Based Services

Sensors, as a primary driver of the IoT (Internet of Things), collect data from their surroundings, which service providers utilize to activate the relevant services. These service providers must have access to a wide range of sensitive personal data. The Internet of Things (IoT) is the next big thing that is predicted to change the way people and objects interact. IoT devices include sensors implanted in the surroundings as well as wearables like biometric sensors that can closely track a person's health and lifestyle [28].

Previous research on sensor data aggregation assumes the deployment of a trustworthy aggregator and so cannot safeguard consumers from an untrusted aggregator. Recent work [29, 30] looks at data aggregation using an untrusted aggregator. Whereas techniques safeguard data privacy better, they are meant to execute data aggregation operations (e.g., summation, average, or minimum). The computing overhead can be high, putting a major strain on resource-constrained devices prevalent in IoT applications.

Sensors play a crucial role in gathering useful data from the city, residents, and the accompanying communication networks that convey the data in real-time. The report provides an examination of several sensors that are commonly utilized in exertions to create smart cities. Insights into different purposes and communication knowledge, as well as the main capability and obstacles encountered while transitioning to a smart city, are offered. Finally, this approach is concerned with how these new sensing capabilities and digitalization advances improve quality of life, rather than just smart urban infrastructure. Smarter communities are defined as ones adjust, and devote in these technologies via apparent as well as comprehensive area involvement regarding to regional and provincial common demands in addition to estimates [31].

7. Discussion: Challenges, Open Issues, and Limitations

Rapid industrialization in some nations is driving people to relocate from rural to urban areas in search of better-paying jobs. This trend began a few years ago and is anticipated to last until at least 2050. While this condition exacerbates problems in many cities, it also gives opportunity for city planners to construct new towns or districts from scratch [32]. Gedikli et al.

provide context for the significance of cities in global climate change and environmental pollution. The paper examines a theoretical framework for smart cities and their key aspects, with an emphasis on technological innovation, smart governance, energy efficiency, waste management, green buildings, smart grid-smart lighting, and smart mobility. It also proposed sustainable development policy recommendations for urban plans and programs within the current legislative framework [33].

Li et al. recommend the social collaboration of renewable energy resources system to overwhelmed challenges like obstruction, a lack of funding for needed services, a deficiency of appropriate housing, deteriorating structure, and strengthening air pollution [34]. IoT, according to this paper, is defined as a network of interconnected gadgets and sensors. It asserts that data should be reduced to a size appropriate for current systems, screened to assure its honesty and compliance with security regulations, and then processed and stored to provide access to those who will benefit from its eventual use. Moreover, an energy management approach according to the findings of mandate response outlines could be utilized in coincidence with demand response schemes to moderate further the amount of power devoted. It enhances residents' quality of life, resulting in 95.4% maximum.

The purpose of sustainable development is to use a knowledge-based strategy to alter people's lives, work, and transportation. Data-driven urbanism is the core mode of creation for smart cities. Popescu et al. summarize the important findings of a large study that investigated the many characteristics and efforts found in environmentally friendly smart cities [35]. However, Anotony et al. investigate current trends and technology for smart cities utilizing an information-driven approach to foster future efficiency and sustainability. The study accomplishes that slightly outline for scheming smart and functional societies depends on modern expressions has premeditated significance in tackling many of the composite matters and concerns that should be stated to conservationism and development, and its advances in accelerating sustainable development.

The smart city notion evolved as an IoT application domain. Among the different concepts that use ICT in urban contexts, such as digital city, green city, sustainable city, intelligent city, and so on, smart city stands out due to its comprehensive vision. In terms of definitions, norms, and ramifications, Silva et al. presented the principles of a smart city. The qualities and attributes are given in a straightforward manner to help you get the gist of the smart city concept [36]. Mishra et al. address that the creation of sustainable smart cities to ensure long-term success, requires rigorous planning, collaboration among parties, effective security measures, and a focus on privacy [37].

AI (artificial intelligence) and AIoT (artificial intelligence of things), as disruptive machineries, provide basic technical infrastructure required for developing the digital ecosystem of emerging smarter eco-cities to amplify and sustain their contributions to environmental sustainability goals. Bibri et al. give a thorough systematic overview of the expanding landscape of smarter eco-cities beside its cutting-edge AI and AIoT solutions in favor of conservational sustainability. Furthermore, the study makes use of a unified evidence synthesis framework that incorporates aggregative, configurative, and narrative synthesis methodologies [38].

Almost every area in the globe is now implementing various pilot initiatives to imitate such smart cities. According to Shamsuzzoha et al. [39], present smart city research does not completely address the complex nature, tensions, and interdependencies of smart city aims. Furthermore, the study discovered that smart city efforts build complex and diverse platforms that demand holistic evaluation, since existing smart city evaluation methodologies and rankings differ significantly, making determining the performance of smart cities challenging. Mishra et al. advance the

partnership of several portions like transportation network and healthcare sector to improve and control the sustainable and smart cities encompassing smart machineries [40].

Cities are at a crossroads of two trends: fast advancing technology and increasing urbanization. These streams may be linked by IoT technology, allowing leaders to better manage urban systems, save natural resources, and improve quality of life. In the energy industry, advanced sensor technology and data analytics in public buildings, paired with developments in microgrids, may minimize overconsumption and promote sustainable energy use. Publishing water and energy use statistics, as well as the accompanying environmental and financial implications, in an easily comprehensible manner which can help educate the public about the importance of IoT for sustainability. IoT technology in transportation may streamline transportation management and empower commuters' decision-making on transit options, decreasing commuter stress while achieving sustainability goals [41].

A component of the IoT (Internet of Things) and linked devices that collects information from appliances and then conducts automated activities based on user priorities and decreased energy use. All these smart strategies provide an orderly timetable for appliance operation during peak hours based on demand response signals. Gupta et al. publish the latest developments in Civil Engineering—quickly, informally and in top quality. The authors addressed that distinguishing the growing importance of cities in sustainable development and the pressing need to address the associated challenges, the UNs identified a new customary of international progress aims known as the SDGs (Sustainable Development Goals) in its post-2015 development agenda, with a vision of a more prosperous, sustainable, and equitable world [42].

To provide decision-supporting information, smart cities require numerous data sources and credible models. It gets extremely difficult when a large number of smart devices and sensors are involved. Liu et al. [43] propose five typical smart-city applications, the data engaged, corresponding models, and their requirements for computing. These applications are transport and traffic management, utilities and energy management, environmental protection and sustainability, public safety and security and urban heat island and urban computing.

Purkait et al. state that the adoption of smart cities to improve the quality of life of its residents has resulted in the economic advancement of several cities throughout the world as well as a rise in government investments in a smart life. Despite the Indian government's enormous efforts to attract foreign investment, tourism, welfare, and other services, the cities continue to face issues and do not match the qualifications for being labeled smart cities. However, technological advancements have inspired a revolution in the efficiency with which people may interact. This removes the barrier that existed to assist the user in his everyday life, allowing the robots to provide solutions in real time. This, however, assumes that everything in the city functions without a hitch [44].

The massive expanse of data is being produced by IoT devices and sensors that supplies the hypothesis of intelligent cities and the future of intelligent transportation systems. Kumar et al. address that techniques such as artificial intelligence, machine learning, and, in particular, dynamic range learning play an essential role in accurately monitoring and quantifying instantaneous-time data transport stream in an urban circumstance [45]. However, Yousefimehr et al. intend to provide an adaptable framework for researchers and practitioners working in a variety of city contexts to adopt and use numerous ideas and guidelines gleaned from the research in the development of smart activities and initiatives [46]. The study explains that smart systems may capture and integrate data through meters, appliances, sensors, and gadgets, and that the data can then be aggregated and evaluated for usage in computer platforms and

communication networks [46, 47].

With technologies combined with a plethora of smart devices and sensors, urban managers may now supplement their decision-making processes by relying on analysis of a plethora of urban data that these devices can gather, store, and transfer to analytical platforms. Allam et al. observed that, despite the increasing number of IoT devices and sensors, collaboration between different market players has been very limited, resulting in the existence of devices that are incompatible and require different networks because their functionalities and protocols are different [48, 49].

Cloud-based apps have recently dominated the market due to their flexibility, affordability, convenience, and ubiquitous access. In recent years, there has been a growing emphasis on equipping cities with Internet of Things-enabled devices for effective monitoring and administration. Recent advancements in wireless communications, such as 4G, have made significant contributions, and there is a rising anticipation in wireless communications with 5G technology. Bakaraniya et al. talked on the 5G enabled smart city framework, potential hurdles, and future projects. The research also looks at how 5G technology may relate to the cloud environment to help with the overall development of smart city applications [50].

Amine et al. provide an important investigation of new approaches in the science and engineering of deploying unique and efficient computer algorithms to improve the efficiency of the networks and communication systems that underpin smart city infrastructure. The book addresses specific difficulties with the implementation of these algorithms with the goal of assisting readers in improving the functioning of smart cities [51]. The study provides content from a varied range of globally famous writers in computer science, electrical engineering, operations research, civil engineering, and the social sciences in a succinct and accessible format. They also examine the use of artificial intelligence to protect the functioning of cyberphysical smart city infrastructure and present various instances of unique theoretical algorithms in action.

It is obvious how shifting the paradigm and promoting the move toward sustainable propulsion technologies, renewable energy sources, low-emission electric public transportation systems, and active and shared cars will have a massive influence on pollution reduction. Because of this, one of the primary advantages of smart mobility is sustainability. Improving environmental conditions, for example, has a direct influence on the image of the city, which becomes greener, more sustainable, and appealing to a range of actors and organizations. Nason et al. address that low consideration for Image Improvement may thus be addressed by stating that it might have been included inside the first aim [52].

Transportation-related initiatives have been undertaken with the purpose of decreasing the environmental effect of transportation. Emissions reduction, renewable energy sources, “green” transportation, and car-free cities. The study states that Green Revolution and Environmental Transition are the missions to which most resources are directed, and 45 investment announcements have been made. Relevant projects range from the implementation of an electric bus fleet to the use of novel technology in the e-vehicle manufacturing chain. 3.6 billion are earmarked for urban mobility: the “Sviluppo trasporto rapido di massa” initiative [53] intends to reduce urban traffic by 10% in chosen cities by promoting a 231km extension of the public transportation network.

In fact, there are some important challenges that face smart cities. These challenges should be taken into consideration when implementing smart cities, especially in developing countries. The first challenge is the technical infrastructure that contains the components that make the operation and management of endeavor IT facilities and IT settings potential. This infrastructure incorporates all hardware, software, networks, and means companies utilize to initiate,

investigate, supply, dominate, and support IT services. Another challenge is specialized human resources. However, IoT may offer a snapshot of current collective workforce productivity and provide staff motivating tactics to boost it [54].

Legislation Issues is another challenge where IoT may offer a snapshot of current collective workforce productivity and provide staff motivating tactics to boost it. The rise of IoT devices introduces flaws that can result in unwanted access, unsecured connections, and data breaches. Hence, hackers and privacy violation are another vital challenge. In addition, improper authentication and permission, unsecured communication protocols, and erroneous software upgrades all pose substantial dangers to IoT devices and networks. Moreover, aliases and hidden identity of citizens is the fifth challenge where some schemes utilize a combination of sensor aliases to hide the uniqueness of the sensing source and per function commencement vector to disclose evidence only to applicable service providers [28].

8. Conclusion

The goal of this study was to undertake a thorough evaluation of the available literature on the role of smart cities in creating more environmentally friendly communities and cities. As indicated by the growing body of research on the issue, smart buildings may assist in achieving a variety of policy objectives. Sustainability in smart cities is likely to fit under the smart environmental topic, according to an assessment of relevant literature. In recent years, there has been various research on these themes that have been examined. Following the observed patterns of population increase and movement to urban areas, it is obvious that cities will confront an ever-increasing requirement to meet the expectations of its residents in the coming years.

Diverse initiatives have been undertaken in cities across all continents to progress toward smartness as a means of improving resource management, providing more efficient and trustworthy services, improving city livability, and encouraging government, university, and public involvement. Deep understanding of each implementation context and key interconnections between sectors (e.g., transport-energy, energy-water-food, resource efficiency and recovery, etc.), as well as meaningful community engagement and involvement in the planning and use of new technologies in urban infrastructure, are required to improve political feasibility, transparency, equity, and financial sustainability.

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