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Leveraging IOT and Big Data for Sustainable Transportation in Smart Cities

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Abstract: The concept of smart cities continues to evolve, facing numerous technological, economic, and governmental challenges that hinder its global implementation. Additionally, the integration of the Internet of Things (IoT) with big data technologies presents significant potential for advancing smart city development, yet this synergy remains underexplored. This study aims to explore the role of big data in the development of sustainable transportation systems within smart cities. Initially, the concept of smart cities is introduced, followed by a discussion of their key features, specifications, and general architecture, including real-world applications. The paper also examines the challenges and opportunities in the field of smart cities, particularly focusing on sustainable transportation systems, data analytics, and the application of big data. Ultimately, this research highlights the pivotal role of Intelligent Transportation Systems (ITS) in shaping sustainable smart cities and sets the foundation for future studies on the challenges and opportunities associated with big data applications for sustainable transportation in smart cities.

Keyword: Big data, Internet of Things (IoT), smart city, Intelligent transportation system.

1. Introduction

According to the latest estimates by the United Nations, approximately 68% of the global population will reside in urban areas by 2050. The report highlights a significant increase in urban populations, from 751 million in 1950 to 4.2 billion in 2018 [1]. Bibri and Krogstie [2] argue that urban areas account for 70% of global natural resource consumption, leading to environmental degradation, ecosystem destruction, and energy shortages. Limited access to essential resources remains a major challenge in urban development, as cities are designed to reduce costs and unemployment, with particular focus on transportation, energy consumption, climate change, and potable water supply.

Given these challenges, there is an urgent need to adopt smart solutions to address the critical issues facing urban development [3]. In this context, smart cities emerge as a potential solution. A "smart city" is a concept employed to enhance the environmental, economic, mobility, safety, governance, and living standards for its residents [4].

1.1 The Concept of a Smart City?

In simple terms, a smart city is one where traditional networks and services are made more adaptable, efficient, and sustainable through the integration of information, digital, and telecommunication technologies. This transformation improves the city's operations for the benefit of its inhabitants, resulting in better public services and more efficient resource use, while minimizing environmental impact.

Marsal-Llacuna et al. [5] defined a smart city as an urban environment that employs information and communication technologies (ICT) and other relevant technologies to enhance the efficiency of urban operations and improve the quality of services (QoS) provided to citizens [6]. The primary goal of the early smart cities was to improve the quality of life (QoL) of residents by addressing the demand-supply imbalances across various functions [7]. In modern smart cities, the focus is placed on sustainability, efficient energy management, transportation, healthcare, and governance, in order to meet the essential requirements of urbanization [8].

The realization of smart cities will necessitate the utilization of vast amounts of data, commonly referred to as big data, which will underpin the services delivered through the Internet of Things (IoT). Big data is characterized by its volume, velocity, and variety of data types, which are continuously expanding [9]. This wealth of data enables cities to gain valuable insights from a wide range of sources, with much of it being unstructured compared to data collected through traditional methods [10].A sustainable transportation system in a smart city is significantly dependent on the implementation of Intelligent Transportation Systems (ITS). ITS has emerged as a transformative force within the rapidly evolving transportation sector, reshaping the way people and goods are transported. By integrating advanced technologies, data analytics, and communication systems, ITS aims to enhance the efficiency, safety, and environmental sustainability of transportation networks [11].

ITS leverages state-of-the-art information and communication technologies to improve various aspects of transportation, including traffic management, vehicle operations, and public transit systems. Its primary objectives are to alleviate traffic congestion, reduce travel times, enhance safety, and minimize environmental impacts, utilizing real-time data, sensor networks, and intelligent algorithms [11,12].

The scope of ITS is broad, encompassing a wide array of applications such as intelligent traffic signal systems, autonomous vehicle technologies, dynamic route planning, electronic toll collection, and real-time public transit tracking. These advancements not only improve the daily transportation experience for individuals but also contribute to broader societal goals, including energy conservation, reduced emissions, and more efficient urban planning.

With the ongoing acceleration of urbanization and the increasing demand for efficient transportation, Intelligent Transportation Systems (ITS) play a pivotal role in shaping the future of mobility. Governments, corporations, and researchers worldwide are dedicating resources to implementing ITS technologies to create smarter, more interconnected, and environmentally sustainable transportation ecosystems.

Intelligent transportation not only improves the driving experience, road safety, and traffic management but also provides significant sustainability benefits by reducing CO_2 emissions and other harmful pollutants [13].

2. Method

This paper aims to explore the critical role of the Internet of Things (IoT) and Big Data in developing sustainable transport systems within smart cities. A brief review of the key characteristics of smart cities, including their architecture, challenges, and opportunities, is provided, alongside an examination of the role of IoT in smart city development.

The needs and challenges associated with big data systems in smart cities are subsequently discussed. This section includes a survey of systematic big data tools for smart cities, focusing on data collection, data pre-processing, and the analysis of processed data. The following section explores the technologies supporting sustainable transport systems within smart cities.

The final section examines case studies from specific urban areas, demonstrating the benefits of integrating Intelligent Transportation Systems (ITS) and their crucial role in promoting Sustainable Smart Cities.

The paper concludes with a summary of potential future research directions. As big data represents a central issue in the development of smart cities, Section 4 addresses the obstacles to its implementation, drawing on various case studies. Unresolved

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issues and future research topics are also discussed. Section 5 presents an innovative big data framework for smart cities, while Section 6 highlights future research opportunities. Finally, Section 7 offers the conclusions.

Based on the literature reviewed, this study is the first to specifically address the challenges related to big data in smart cities. In this context, the present article provides a foundation for future research aimed at advancing the development of smart cities grounded in big data principles.

Intelligent transportation systems not only enhance driving experiences, road safety, and traffic management but also provide substantial sustainability benefits by reducing CO2 emissions and other harmful pollutants [13].

3. Overview of Smart Cities and IoT

A smart city can be broadly defined as an urban area where traditional networks and services are made more flexible, efficient, and sustainable through the integration of information, digital, and telecommunication technologies. These innovations are designed to improve the operations of the city for the benefit of its inhabitants. Smart cities are characterized by being greener, safer, faster, and more user-friendly. The key components of a smart city include smart infrastructure, smart transportation, smart energy, smart healthcare, and smart technology. These elements work together to make the city more intelligent and efficient. Information and communication technology (ICT) plays a critical role in transforming traditional cities into smart cities [14].

According to Albino et al. [15], a smart city encompasses a range of paradigms across diverse domains, including the economy, public services, government, mobility, environment, and lifestyle. This concept integrates various fields such as environmental monitoring, traffic analysis, utility monitoring, public transportation, and incident reporting. The collection of data from these areas enables city authorities to enhance infrastructure and optimize resource management [16]. For a city to be considered "smart," it must incorporate key elements that centralize the data. These elements can take various forms, from simple web pages to complex, context-aware mobile applications or specialized hardware [17], [18]. Additionally, ensuring data accessibility is essential, enabling the system to be freely accessible to citizens while also allowing them to modify and correct information as needed.

A comprehensive overview of the components required for a smart city is illustrated in Figure 1.

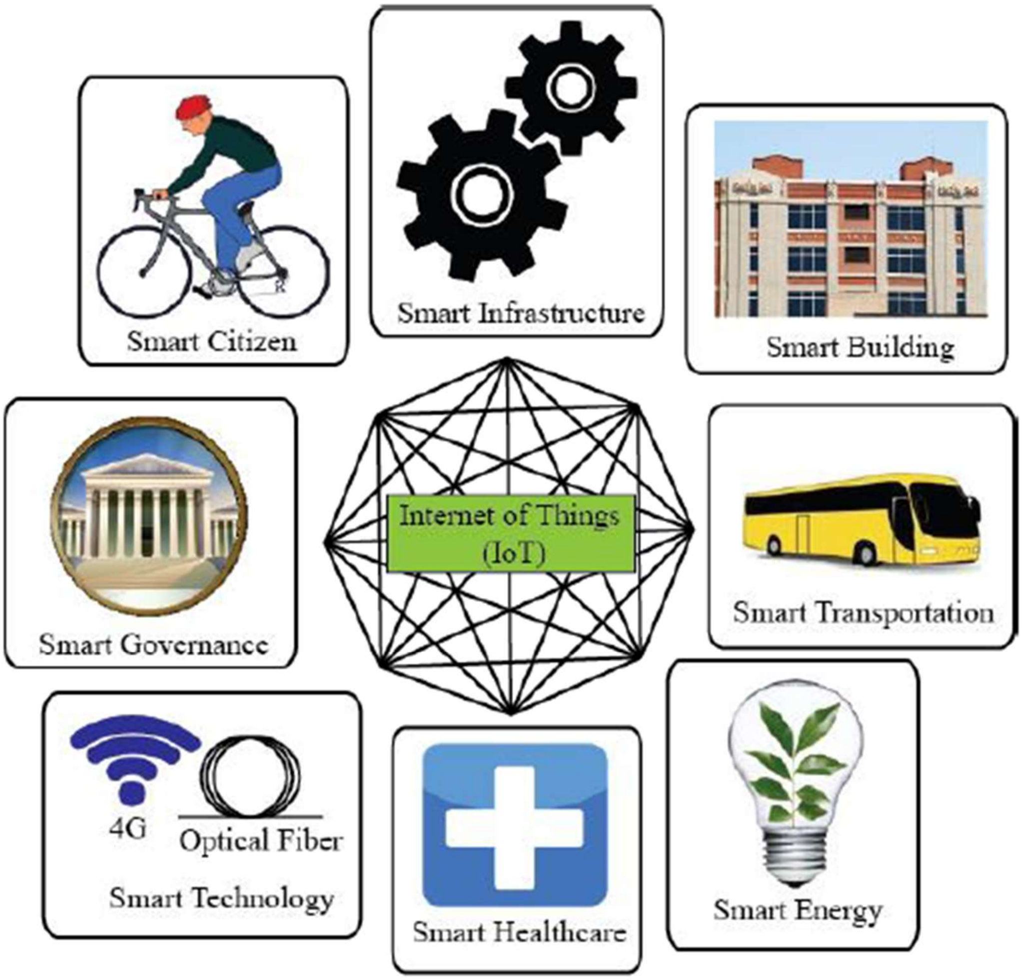

Figure 1a. A broad overview of smart city components

A city does not necessarily need to possess all smart components to be classified as "smart." The extent to which a city incorporates smart components depends on factors such as cost and the available technology.

The emergence of the Internet of Things (IoT) has transformed the abstract notion of the smart city into a tangible reality. Smart cities are designed to enhance the quality of life for their residents by providing superior healthcare, safety, convenience, and intelligence. In essence, the objective of smart cities is to improve overall living conditions. IoT can be considered one of the most effective technologies, driving a profound transformation across the globe . It represents an advanced iteration of traditional networks, designed to connect a vast array of interconnected devices. This concept of IoT is further strengthened by the integration of cutting-edge technologies, including wireless sensor networks (WSNs) and machine-to-machine (M2M) communication. An architecture of IoT is shown in figure 1.b.

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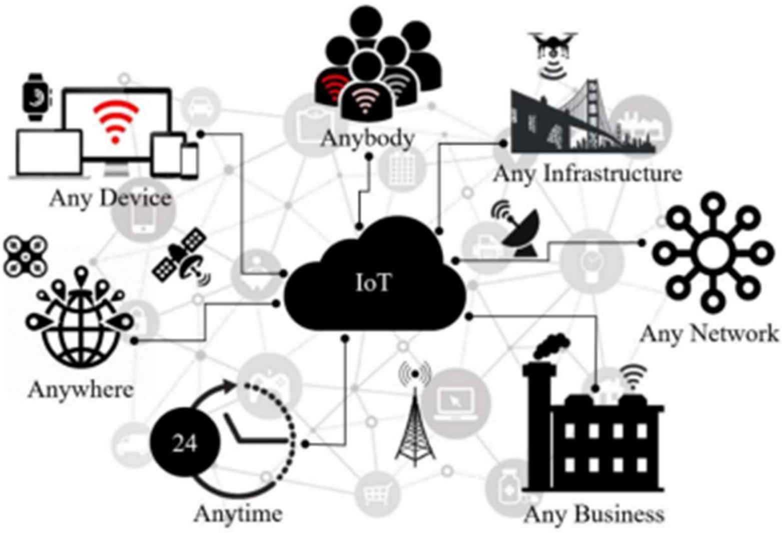

Figure 1b. An overview of IoT

3.1 Smart Cities: Components and Characteristics

The components and characteristics of a smart city are summarized in Figure 2. A smart city is composed of various elements, and the figure highlights eight key components. These components include: smart infrastructure, smart buildings, smart transportation, smart energy, smart healthcare, smart technology, smart governance, smart education, and smart citizens. A brief discussion of each of these components will follow in the subsequent sections. It is important to note that the presence and focus on these components may vary among different smart cities, depending on their unique priorities and developmental goals.

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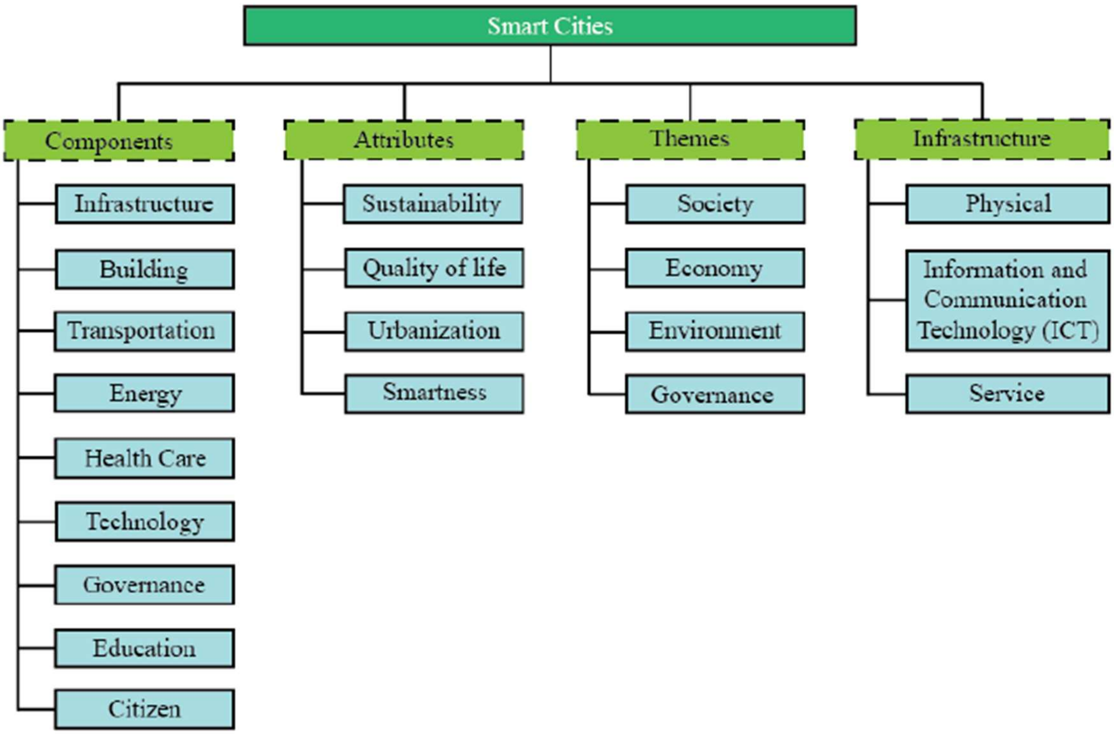

Figure 2. Components and characteristics of Smart Cities

The key attributes of smart cities encompass sustainability, quality of life (QoL), urbanization, and smartness. Sustainability in a smart city is closely linked to aspects such as city infrastructure and governance, energy management, climate change, pollution control, waste management, as well as social, economic, and health considerations. Quality of life (QoL) is typically assessed based on the emotional and financial well-being of the city's residents. The urbanization characteristics of a smart city involve various dimensions, including technology, infrastructure, governance, and economic development. The concept of smartness in a smart city is framed as the drive to enhance the economic, social, and environmental conditions for both the city and its inhabitants. Commonly recognized elements of a smart city's "smartness" include a smart economy, smart people, smart governance, smart mobility, and smart living.

4. IoT and Big Data analytics for sustainable transportation

The Internet of Things (IoT) and Big Data analytics have emerged as transformative technologies, enabling the seamless interaction of data, people, and interconnected physical objects through the exchange of information. These technologies have found widespread adoption across various sectors, including manufacturing, agriculture, banking, oil and gas, healthcare, retail, hospitality, and food services. The transportation industry, in particular, has been an early adopter, with substantial impacts on processes such as shipment tracking, freight monitoring, and warehouse transparency. Notable implementations of IoT and Big Data analytics in transportation can be observed in countries such as England, Singapore, Portugal, and Germany. Meanwhile, Malaysia is currently exploring the potential of these technologies, conducting research to assess their viability and purpose-driven adoption [19].

The transportation sector is at the forefront of implementing IoT technologies, rapidly adopting innovations to stay competitive, boost productivity, improve profitability, and enhance customer loyalty and satisfaction. This adoption is especially crucial due to the low-margin, fragmented nature of the transportation industry. IoT has played a key role in addressing the growing need for supply chain transparency and supporting data-driven decision-making within a connected and distributed network [20]. One notable IoT technology is the track-and-trace global positioning system (GPS), which was initially used for shipment tracking before the rise of radio-frequency identification (RFID) technology. Today, IoT technology is integral to nearly every aspect of the logistics chain, including warehousing, freight transportation, and last-mile delivery, with an estimated €16.8 trillion investment stake [21]. Countries like Portugal [22], Germany [20], England [22], and Singapore [23] are leading the way in adopting IoT and big data analytics to revolutionize their transportation systems. A broad illustration of the smart transportation is presented in Fig. 3

Figure 3. illustration of Smart Transportation [24]

The smart transportation system has enabled the construction of global airway hubs, intercity railway networks, intelligent road networks, protected cycle routes, protected pedestrian paths, and integrated public transport systems, all designed for safe, rapid, cost-effective, and reliable transportation. The integration of ICT and real-time data processing has made these advancements possible. This system maximizes the utilization of vehicles in the network, such as the number of aircraft in an airline's fleet or the number of trains in a railway system. It allows passengers to easily choose transportation options based on cost, shortest distance, or fastest route.

With the implementation of big data technology in smart cities, data can be efficiently stored, processed, and transformed into actionable knowledge, which enhances the development of smart city services. Additionally, big data can aid in the expansion of services and resources. Advanced tools and approaches lead to highly efficient and effective data analysis, fostering cooperation and communication between service providers in various sectors of the smart city, ultimately improving customer satisfaction and creating new business opportunities.

5. Technologies for sustainable transport systems in smart cities

As cities grow in population, they face significant challenges such as transportation congestion, energy consumption, and pollution. To address these issues, cities are increasingly turning to smart technology, which integrates diverse systems and sensors to enable real-time data collection, analysis, and decision-making.

Smart cities and intelligent transportation systems (ITS) are highly reliant on reliable communication technologies. The advent of technologies like the Internet of Things (IoT) and 5G communications has accelerated the adoption of ITS in recent years.

Key technologies for sustainable transportation systems under the ITS umbrella include Vehicular Ad-hoc Networks (VANETs), Intelligent Traffic Lights (ITL), Virtual Traffic Lights (VTL), and Mobility Prediction. These technologies are fundamental to the smart city revolution. ITS plays a critical role in reducing vehicle idle time, prioritizing emergency vehicles, shortening emergency response times, improving traffic efficiency, preventing collisions, and reducing carbon emissions. The integration of 5G real-time communication can further enhance the effectiveness of these technologies.

Research indicates that intelligent transportation systems (ITS)-based traffic management solutions can lead to a significant reduction in travel times, with potential savings of up to 25%, providing substantial benefits for commuters. By optimizing traffic signal timings, these systems also contribute to a reduction in energy consumption and greenhouse gas emissions, with estimates suggesting a decrease of approximately 15-20%. Additionally, a survey conducted in urban settings revealed that the implementation of intelligent traffic management systems can reduce accidents in metropolitan areas by up to 20%. This improvement is largely attributed to enhanced coordination of traffic flow and more effective real-time incident management.

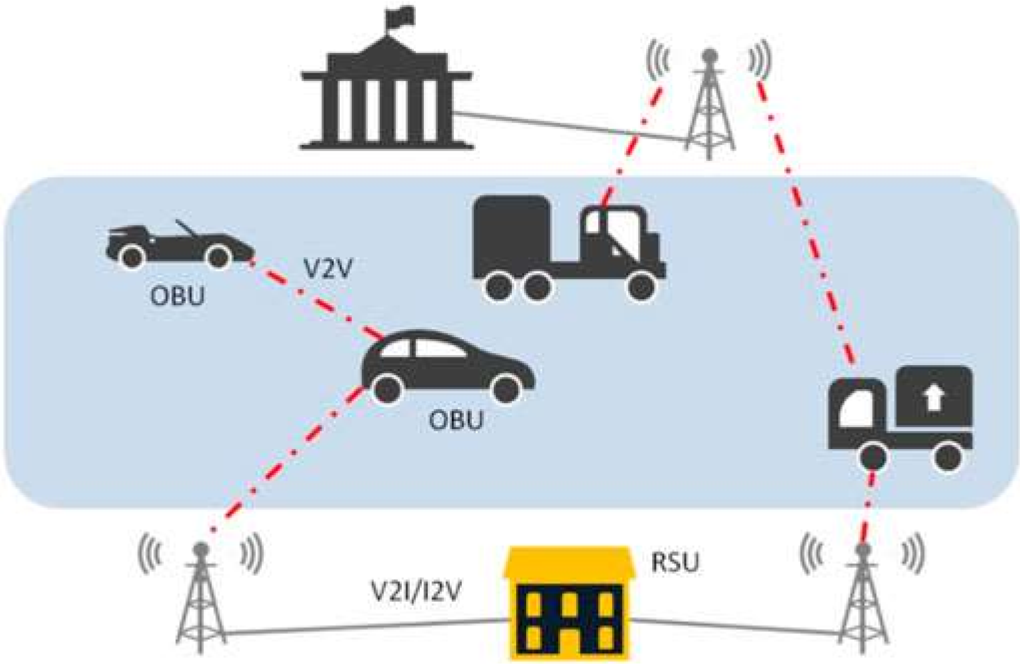

Figure 4. types of VANETs

Vehicle-to-pedestrian (V2P) communication is particularly advantageous at intersections, as illustrated in Figure 4. These figures demonstrate the real-time transmission of warning messages to pedestrians' smartphones and vehicle displays via a cellular network. This communication system is especially effective when a vehicle approaches an intersection, and a pedestrian unexpectedly enters the road without noticing the approaching vehicle, which may be traveling at high speed. By providing timely alerts, V2P communication plays a crucial role in reducing the risk of traffic accidents [25], [26].

Vehicle-to-everything (V2X) communication integrates all critical types of vehicular ad-hoc networks (VANETs), including vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-pedestrian (V2P), and vehicle-to-network (V2N), enabling vehicles to seamlessly interact with their surrounding environment. This system facilitates the exchange of data from the cloud, provides notifications and warnings about pedestrians suddenly crossing streets, enables communication with other vehicles regarding speed, vehicle status, and directions, and connects to road infrastructure, such as intelligent traffic lights and sensors, to provide real-time updates on road congestion and traffic flow. These capabilities support the efficient operation of autonomous driving systems.

5.1 Intelligent Traffic Lights (ITLs)

Intelligent traffic lights (ITLs) are integral to intelligent transportation systems (ITS) as they play a key role in managing traffic flow and enhancing road safety. ITLs utilize real-time traffic data and sophisticated algorithms to optimize traffic movement and reduce congestion [27]. These systems collect real-time traffic data through various devices, including cameras, radar sensors, and other monitoring equipment [28]. The collected data is then processed using advanced algorithms to determine the optimal scheduling for traffic signals, taking into account factors such as traffic volume, congestion levels, and pedestrian movement. This approach contrasts with traditional traffic lights, which operate on fixed timing intervals [29]. For example, ITLs can dynamically adjust signal timings to alleviate congestion in areas with high traffic demand, resulting in reduced idling time and lower CO2 emissions from vehicles. Additionally, ITLs are capable of detecting bicycles and pedestrians, providing them with designated safe crossing periods, thereby reducing accident rates [30].

5.2 The Impact of ITS Implementation on the Environment and Sustainability in Smart Cities

Sustainability is defined as meeting the needs of the present without compromising the ability of future generations to meet their own needs. The integration of Intelligent Transportation Systems (ITS) technologies with 5G communication can facilitate the development of eco-friendly transportation systems in smart cities. Key components of ITS, such as Vehicular Ad-hoc Networks (VANETs), Intelligent Traffic Lights (ITLs), and Virtual Traffic Lights, utilize real-time communication technologies to enhance traffic flow and reduce congestion. These advancements contribute to decreased fuel consumption and lower emissions, thereby mitigating the environmental impact of transportation and supporting sustainability goals.

The incorporation of 5G real-time communication within smart cities further optimizes the performance of ITS technologies by enabling faster and more accurate data collection, analysis, and decision-making. These improvements lead to reductions in energy consumption and emissions, while simultaneously enhancing safety—both of which are critical factors in achieving sustainable urban environments and transportation systems [27].

In the context of establishing a Sustainable Smart City, the transportation sector is often prioritized for transformation into an Intelligent Transportation System (ITS). Globally, governments are confronting numerous challenges, including excessive energy consumption, air pollution, traffic congestion, high accident rates, poor driving experiences, prolonged idling times for drivers, and increased fuel consumption [31]. As urban populations grow due to migration from rural areas in search of better economic opportunities and living conditions, cities are experiencing significant traffic congestion. The transition to a Sustainable Smart City provides an ideal solution to address these issues. Implementing technologies such as ITS, Smart Buildings, and Smart Manufacturing is essential for transforming cities into environmentally responsible and efficient urban centers. This transformation not only improves safety and reduces fuel consumption, traffic congestion, and accidents but also significantly contributes to sustainability by decreasing energy use and lowering greenhouse gas emissions [31].

The implementation of Intelligent Transportation Systems (ITS) plays a vital role in improving traffic flow, reducing harmful gas emissions, lowering air pollution, minimizing idling time for drivers, and enhancing the overall driving experience, all of which contribute to the promotion of sustainability. The integration of ITS technologies and 5G real-time networks has led to significant advancements in the performance of Sustainable Smart City initiatives across various global cities.

The deployment of ITS, supported by real-time communication technologies, is instrumental in reducing CO2 emissions from vehicles, thereby facilitating the movement of cities toward eco-friendly environments. One notable example is Intelligent Traffic Lights (ITLs), which optimize traffic flow, decrease idling times, and reduce the frequency of stops and starts at intersections. ITLs utilize advanced sensors, big data analytics, and machine learning to dynamically adjust traffic signals based on real-time traffic conditions, congestion levels, and other variables [27].

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The ITL system collects data on traffic patterns, vehicle speeds, and the distance required for approaching vehicles to reach the traffic light using Road Side Units (RSUs) as sensors and cameras installed along roadways. This information is then used to predict the most appropriate light timings, aligning with the flow of traffic to minimize vehicle idling times and reduce the need for frequent acceleration and braking. By doing so, ITLs help to reduce CO2 emissions and enhance fuel efficiency, supporting both environmental and economic sustainability objectives [32].

Smart Parking is an innovative technology that contributes to the reduction of CO2 emissions. It utilizes Road Side Units (RSUs) and communication technologies to provide real-time information to drivers about available parking spaces via mobile applications. This system relies on the deployment of sensors or cameras within parking spaces to detect the presence and movement of vehicles. These sensors are connected to RSUs, which collect and transmit real-time data on available parking slots. The RSUs then relay this information to vehicles, directing them to the nearest available parking spaces. As a result, drivers can avoid unnecessary circling or waiting for a parking space to become free, thereby reducing fuel consumption and minimizing CO2 emissions.

Intelligent Transportation Systems (ITS) play a crucial role in fostering sustainable cities by reducing energy waste, lowering pollutant emissions, and enhancing the safety and livability of urban environments. Beyond CO2, other pollutants such as hydrocarbons (HC), carbon monoxide (CO), particulate matter (PM), nitrogen oxides (NOx), sulfur dioxide (SO2), and PM2.5 and PM10 pose significant health risks. For instance, PM2.5 and PM10 can adversely affect lung development and growth in children over time, leading to long-term respiratory issues [33].

Several municipalities have undertaken significant investments in Intelligent Transportation Systems (ITS) and environmentally sustainable transportation solutions. These municipalities have collaborated with various industries to advance the development of Sustainable Smart Cities, yielding substantial positive outcomes. Section 5.1 presents case studies that examine the efforts of specific cities in transitioning towards Sustainable Smart Cities. Notable examples include Los Angeles (USA), Montreal (Canada), Singapore (Singapore), Barcelona (Spain), Copenhagen (Denmark), Seoul (South Korea), Dubai (UAE), and the New Administrative Capital (Egypt).

6. Conclusion

Numerous municipalities have made considerable investments in Intelligent Transportation Systems (ITS) and environmentally sustainable transportation solutions. Through collaboration with diverse industries, these municipalities have advanced the development of Sustainable Smart Cities, resulting in significant positive outcomes. Section 5.1 presents case studies that explore the efforts of specific cities in their transition towards Sustainable Smart Cities. Noteworthy examples include Los Angeles (USA), Montreal (Canada), Singapore (Singapore), Barcelona (Spain), Copenhagen (Denmark), Seoul (South Korea), Dubai (UAE), and the New Administrative Capital (Egypt).

Table 1: the Summary of IoT and Big data analytics Implementation in Transport sector of some countries

Countries	Problems (before the implementation of IoT and Big data analytics)	Results (after the implementation of IoT and Big data analytics)
Portugal	Recurring cases of fatal accidents due to non-compliance with speed limits	Behavioral change in the drivers' eco-driving, then drastic reduction in the cases of fatal car accidents
Germany	Road safety concern, traffic congestion, and pollution.	Eco-friendliness, and hitch-free traffic flow
England	Operational waste and workers' safety	Operational waste reduction and safe working environment
Singapore	Unpleasant passenger's booking experience	Better passenger's booking experience

The adoption and implementation of Internet of Things (IoT) technologies and big data analytics offer substantial benefits, as evidenced by their widespread application across various sectors, including hospitality, oil and gas, security, healthcare, and transportation, which is the primary focus of this paper. Countries such as Portugal, Germany, the United Kingdom, and Singapore have been at the forefront of applying IoT and big data analytics to address various challenges in their transportation sectors. These challenges include frequent fatal car accidents, increased port traffic and congestion, operational inefficiencies, and bus passenger preferences.

Recent technological advancements, such as IoT, Vehicle-to-Everything (V2X) communication, and 5G networks, have facilitated the deployment of innovative solutions, such as Intelligent Traffic Lights (ITL) and Virtual Traffic Lights (VTL). By leveraging real-time communication through 5G networks and incorporating various sensor technologies, including AI cameras, Roadside Units (RSUs), and On-Board Units (OBUs), along with ITL and VTL systems, it is possible to effectively optimize traffic flow and reduce CO_2 emissions.

IoT and big data analytics, as integral components of the broader Industrial Internet, are driving significant disruptions in business models and service delivery methods. It is essential for technology providers, adopters, policymakers, and all stakeholders within the transportation sector to collaborate effectively. Efforts should be made to raise market awareness about successful use cases, identify strategic partners within the sector's technological ecosystem, revisit industry regulations and policies, and implement new training models for the workforce. These actions will collectively help realize the full potential of IoT and big data analytics within the transportation sector.

Future works

Future developments in Intelligent Transportation Systems (ITS) will be heavily influenced by the integration of emerging technologies such as artificial intelligence (AI), machine learning, the Internet of Things (IoT), and 5G connectivity. These advancements will enable real-time data collection, analysis, and decision-making, which will contribute to more efficient traffic management, dynamic routing, and predictive maintenance of transportation infrastructure.

The widespread adoption of Autonomous Vehicles (AVs) is expected to significantly transform urban transportation systems. As AVs become more prevalent, ITS will need to evolve by incorporating infrastructure enhancements, including smart traffic lights, dedicated AV lanes, and communication systems that facilitate vehicle-to-vehicle and vehicle-to-infrastructure interaction. AVs hold the potential to improve safety, reduce congestion, and optimize energy consumption within transportation networks.

Additionally, the vast amount of data generated by IoT sensors, GPS devices, traffic cameras, and mobile applications will provide valuable insights into traffic patterns, commuter behavior, and infrastructure performance. The use of advanced analytics and AI algorithms will enable cities to optimize transportation networks in real-time, respond more effectively to incidents, and strategically plan future infrastructure investments.

Vehicular Ad-hoc Networks (VANETs) will further enhance dynamic traffic management systems, allowing for real-time responses to traffic conditions. Vehicles will receive route recommendations based on current traffic flow, road conditions, and individual preferences, leading to more balanced traffic distribution, reduced travel times, and minimized emissions.

Safety remains a critical concern within transportation systems, and Vehicular Ad-hoc Networks (VANETs) play a vital role in supporting advanced safety applications such as collision avoidance systems, blind spot detection, and intersection assistance. By enabling real-time communication of vehicle speed, position, and intentions, VANETs allow vehicles to anticipate potential collisions and take preventive actions, thereby significantly reducing the risk of accidents and improving road safety.

Moreover, mobile phones equipped with sensors and cameras are anticipated to serve as cost-effective tools for collecting driving data and facilitating connectivity within VANETs and Intelligent Transportation Systems (ITS) ecosystems. However, it is important to recognize that cloud system architectures, while effective for data collection, may introduce latency-related delays. Multi-access edge computing (MEC), integrated with 5G networks, is emerging as a more efficient alternative by bringing computational power and storage resources closer to the edge of the mobile network. MEC has demonstrated reduced delays compared to cloud systems, thereby enabling real-time decision-making and enhancing driver safety.

Furthermore, the integration of Driver Drowsiness Detection systems within ITS is essential for ensuring both driver and passenger safety. These systems detect signs of drowsiness and alert nearby vehicles. In Internet of Vehicle networks, critical signals from vehicles are transmitted wirelessly to traffic management platforms, which can then trigger alerts to the driver, activate autopilot for safe parking, or warn surrounding vehicles about the presence of a drowsy driver.

References

[1] H. Nasiri, S. Nasehi, and M. Goudarzi, "Evaluation of distributed stream processing frameworks for IoT applications in Smart Cities," J. Big Data, vol. 6, no. 1, pp. 1–24, 2019.

[2] S. E. Bibri and J. Krogstie, "Smart sustainable cities of the future: An extensive interdisciplinary literature review," Sustain. Cities Soc., vol. 31, pp. 183–212, 2017.

[3] C. Liao and L. Nong, "Smart City Sports Tourism Integration Based on 5G Network and Internet of Things," Microprocess. Microsyst., p. 103971, 2021.

[4] A. Abella, M. Ortiz-de-Urbina-Criado, and C. De-PablosHeredero, "A model for the analysis of data-driven innovation and value generation in smart cities' ecosystems," Cities, vol. 64, pp. 47–53, 2017.

[5] M. L. Marsal-Llacuna, J. Colomer-Llinàs, and J. MeléndezFrigola, "Lessons in urban monitoring taken from sustainable and livable cities to better address the Smart Cities initiative," Technol. Forecast. Soc. Change, vol. 90, pp. 611–622, 2015.

[6] B. N. Silva, M. Khan, and K. Han, "Towards sustainable smart cities: A review of trends, architectures, components, and open challenges in smart cities," Sustain. Cities Soc., vol. 38, pp. 697– 713, 2018.

[7] P. Brous, M. Janssen, and P. Herder, "The dual effects of the Internet of Things (IoT): A systematic review of the benefits and risks of IoT adoption by organizations," Int. J. Inf. Manage., vol. 51, p. 101952, 2020.

[8] J. Souza, A. Francisco, C. Piekarski, and G. Prado, "Data Mining and Machine Learning to Promote Smart Cities: A Systematic Review from 2000 to 2018," Sustainability, vol. 11, no. 4, p. 1077, 2019.

[9] H. M. Kim, S. Sabri, and A. Kent, "Smart cities as a platform for technological and social innovation in productivity, sustainability, and livability: A conceptual framework," in Smart Cities for Technological and Social Innovation, Academic Press, 2021, pp. 9–28.

[10] M. I. Pramanik et al., "Privacy preserving big data analytics: A critical analysis of state-of-the-art," Wiley Interdiscip. Rev. Data Min. Knowl. Discov., vol. 11, no. 1, p. e1387, 2021.

[11] T. Khalid, A.N. Khan, M. Ali, A. Adeel, A. ur Rehman Khan, J Shuja, ' A fog-based security framework for intelligent traffic light control system', Multimed Tools Appl, 78 (17) (2018), pp. 24595-24615, 10.1007/s11042-018-7008-z View at publisherGoogle Scholar

[12] C.T. Barba, M.Á. Mateos, P.R. Soto, A.M. Mezher, M.A. Igartua, 'Smart city for VANETs using warning messages, traffic statistics and intelligent traffic lights' IEEE Xplore (2013), 10.1109/IVS.2012.6232229

[13] H. Noori, ' Modeling the impact of VANET-Enabled traffic lights control on the response time of emergency vehicles in realistic large-scale urban area', Proceedings of the 2013 IEEE International Conference on Communications Workshops (ICC) 2013 (2013), Article 6649290, 10.1109/iccw

[14] Mohanty, Saraju, 'Everything You Wanted to Know About Smart Cities'. IEEE Consumer Electronics Magazine. 5. 60-70. 10.1109/MCE.2016.2556879, 2016)

[15] V. Albino, U. Berardi, and R. M. Dangelico, "Smart cities: Definitions, dimensions, performance, and initiatives," J. Urban Technol., vol. 22, no. 1, pp. 3–21, 2015.

[16] L. Al-Awami and H. S. Hassanein, “Robust decentralized data storage and retrieval for wireless networks,” Comput. Networks, vol. 128, pp. 41–50, 2017.

[17] M. T. Quasim, M. A. Khan, F. Algarni, and M. M. Alshahrani, “Fundamentals of Smart Cities,” in Smart Cities: A Data Analytics Perspective, Springer, Cham., 2021, pp. 3–16.

[18] J. Tian and L. Gao, “Using data monitoring algorithms to physiological indicators in motion based on Internet of Things in smart city,” Sustain. Cities Soc., p. 102727, 2021.

[19] Hussein, Waleed & Kamarudin, Latifah & AL-Hashimi, Haider & Zakaria, Ammar & Ahmad, R.Badlishah & Binti Zahri, Nik Adilah Hanin. The Prospect of Internet of Things and Big Data Analytics in Transportation System. Journal of Physics: Conference Series. 1018. 012013. 10.1088/1742-6596/1018/1/012013.), 2018

[20] Thulesius, M., Digital Transformation of Ports: A Status of the Port of Hamburg and the Port

of Singapore. 2016.

[21] Clarke, R.Y., Smart cities and the internet of everything: The foundation for delivering next generation citizen services. Alexandria, VA, Tech. Rep, 2013.

[22] Tezel, A., et al., Benefits of visual management in construction: cases from the transportation

sector in England. Construction Innovation, 2017. 17(2): p. 125-157.

[23] Menon, A. and R. Sinha, Implementation of Internet of Things in Bus Transport System of

Singapore. 2013.

[24] Saraju P. Monaty, Everything You Wanted to Know About Smart Cities , Article in IEEE Consumer Electronics Magazine · July 2016, DOI: 10.1109/MCE.2016.2556879

[24] “Telecommunications and Smart Traffic Management Systems,” Utilities One. https://utilitiesone.com/telecommunications-and-smart-traffic-management systems# (accessed Mar. 09, 2024).

[25] P.K. Singh, S.K. Nandi, S.A Tutorial Nandi Survey on vehicular communication state of the art, and future research directions Veh. Commun., 18 (2019), Article 100164, 10.1016/j.vehcom.2019.100164

[26] L.M. Ang, K.P. Seng, G.K. Ijemaru, A.M. Zungeru Deployment of IoV for smart cities: applications, architecture, and challenges, IEEE Access, 7 (2019), pp. 6473-6492, 10.1109/ACCESS.2018.2887076

[27] H.A. Khattak, H. Farman, B. Jan, I.U. Din, ‘Toward integrating vehicular clouds with IoT for smart city services’ IEEE Netw., 33 (2) (2019), pp. 65-71, 10.1109/mnet.2019.1800236

[28] M.K. Abbas, M.N. Karsiti, M. Napiah, B. Samir, ‘Traffic light control using VANET system architecture’, Proceedings of the IFIP International Conference on Network and Parallel Computing (2011)

[29] M. Razavi, M. Hamidkhani, R. Sadeghi, ‘Smart traffic light scheduling in smart city using image and video processing IEEE Xplore (2019), 10.1109/IICITA.2019.8808836

[30] S. Kwatirayo, J. Almhana, Z. Liu , ‘Adaptive Traffic Light Control using VANET: a case study’

IEEE Xplore (2013), 10.1109/IWCMC.2013.6583651

[31] K. Sahu, R.K. Srivastava, S. Kumar, M. Saxena, Bineet Kumar Gupta, R. Verma ‘Integrated hesitant fuzzy-based decision-making framework for evaluating sustainable and renewable energy’

Int. J. Data Sci. Anal., 16 (3) (2023), pp. 371-390, 10.1007/s41060-023-00426-4

[32] Xiao Zhende, Xiao Zhu, Wang Dong, Li Xiaohong, 'An intelligent traffic light control approach for reducing vehicles CO_2 emissions in VANET', Proceedings of the 12th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD) 2015 (2015), 10.1109/fskd.2015.7382270

[33] Xiao Zhende, Xiao Zhu, Wang Dong, Li Xiaohong, 'An intelligent traffic light control approach for reducing vehicles CO_2 emissions in VANET', Proceedings of the 12th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD) 2015 (2015), 10.1109/fskd.2015.7382270