ABS International Journal of Management
Volume XIII Issue 1 June 2025 | ISSN 2319-684X (PRINT)

A Study of Sustainable Urban Development and Environment

Prof Sarita Chaudhary
Assistant Professor
Aggarwal College, Ballabhgarh

Mr. Siddhartha Ahuja
Student
Christ University, Delhi NCR

Dr Babita
Assistant Professor
Christ University, Delhi NCR

ABSTRACT:
There is a growing awareness everywhere that coming up with a sustainable form of urban development is a herculean task given the fact that many cities are rapidly expanding and that the effects of climate change have recently become apparent across the globe. Discussing AI and other innovative technologies in this chapter, the role of the AI transformation with regards energy, water, and waste in urban environments is examined. This paper shows that the incorporation of AI into GIS (Geographic Information System) makes it possible for smart sustainable cities to provide for the increasing population while considering the environment. Green infrastructure includes wide ranging elements such as green roofed buildings, tree canopy and planted city and utility corridors, rain gardens, and wetlands, all of which improve urban areas and make the air cleaner, support local ecosystems, and manage stormwater. However, reaching the maximum level of effectiveness in these systems is possible only with artificial intelligence – the latter is an enabler of such systems. This chapter focuses on aspects of AI and green infrastructure to demonstrate that AI could bring the transformation of urban resource management as well as improvement of sustainability objectives. AI enables the smart grid applications that enable the efficient use of power by predicting the need for power, controlling the renewable and the storage systems. Technologically advanced sustainable structures harness smart controls for lighting, heating and cooling for available weather conditions, people occupancy and price of energy for the aim of conservation of energy. In addition, smart streetlight system optimizes energy consumption by adapting to the existing light intensity and individuals' traffic.

Keywords: *Artificial Intelligence (AI) ,Green Infrastructure, Smart Cities, Energy Efficiency, Climate Resilience, IoT (Internet of Things), Resource Optimization, Urban Sustainability*

INTRODUCTION

The increasing rate of urbanization and rising impacts of climate change have you made it crucial to adopt new measures toward sustainable city development. The synergy of artificial intelligence (AI) with green infrastructure provides numerous opportunities for upgrading energy efficiency, making better use of resources together with creating sustainable urban development. Infrastructure can be defined as green infrastructure systems including parks, wetlands, green roofs, smart water systems, and many others that offer ecological functions while responding to urban issues for instance pollution, stormwater management, and climate change adaptation. Machine learning, IoT and predictive analytics are definitions for an extensive range of concepts that can be utilized as lexicon for integrating ultrarealistic real-time data interpretation and intelligent decision making into the plan and operation of smart cities. This Chapter discusses the relationship between AI and green infrastructure with a view to determine how AI-inspired technologies have the potential to transform resource utilization, In the water resource management, areas that artificial intelligence excels in include; accurate prediction of water requirement, automation of smart water management systems, and prevention of floods in urban areas, through the analysis of the meteorological data. Similarly to transportation, in waste management AI improves waste collection plans, improves recycling through vision systems and assists in adaptive policymaking on waste management. Best practice examples from cities globally also show how using AI helps to enhance green infrastructure. Singapore has smart grid applications in managing intelligent energy systems incorporating solar energy into cities. Predictive models are used in Amsterdam to contend with water levels with regards to city flooding concerns. Barcelona employs smart management systems for controlling the environment and emissions and San Francisco employee. AI to increase recycling and efficiency of waste management in the country. However, the use of AI in such environments has its gaps such as, the data privacy issue, the issues of algorithms and the financial or technical means to implement the technologies among others. Adoption transparency, participatory system design integrated within governance structures to

enhance fairness, and stakeholder engagement. Overcoming these barriers remain indispensable to realizing a generation of AI-enhanced urban societies that are inclusive, socially-just and durable. promote climate friendly developments, and respond to various challenges of operation management in cities. In discussing such aspects, the chapter tries to offer practical information on how sustainability objectives might be valid for present and future towns. The Paper also explores the relationship between AI and environmental conservation and points to the opportunity offered by IoT, big data analytics and AI towards improving on real-time monitoring of environmental conditions and support sound climate action plans. Also, it discusses new trends, for instance, application of the intelligent digital twins for modelling of the urban processes, and application of AI for enabling circular economies. To sum up, I argue that, although the visions of using AI for green infrastructure and sustainable urban development are promising, achieving this vision requires joint efforts of urban planners, policymakers, and AI technology and software makers. When cities establish sentinel AI systems that are secure, representative, and transparent, cities can build viable, effective, and sustainable cities. This chapter presents proactive best practices and directions

Literature Review

Bahadure Pankaj(2012) - As challenges lie in the ability to cope, the later part of the paper confers the sustainable development approaches in India. It has been studied under the antecedent of legal provisioning, various policies and programs, institutional arrangements, technological solutions, frameworks and measurement systems for a better present and future.

Bera Sarbani (2020) - Sustainable urban development deals with several problems such as like inadequate housing and slums problem, Urbanization, urban poverty, water supply and sanitation, pollution, solid waste management and health problems etc.

Dr Gupta Manisha et al (2023) - The most important aspect that we can say for the city being smart is that the city equipped with all the basic amenities such as electrification, sanitation, clean drinking water and other infrastructure like road, rail and air connectivity.

Trindade Evelin Priscila et al (2017) - This paper aims to analyze scientific studies focusing on both environmental sustainability and smart city concepts to understand the relationship between these two. In order to do so the study identifies information about researchers, models, frameworks and tools focused on the chosen themes.

Dogan Basak Ozarslan (2024) - Smart urbanization has come to the fore as a solution to the sustainability problems arising from environmental and social reasons in recent years, and today, sustainable development depends on accessing smarter solutions. To be defined as a smart city, it must ensure sustainable growth and development.

Mishra, Kumari, Janaki Krishna and Dubey (2022) - Although urban development is very strong and systematic in developed countries, smart city development in developing countries like India faces various challenges such as delayed investments, coordination of stakeholders at local, state and central levels, timelines and job displacement.

Methodology

The research for this chapter follows a mixed-methods approach combining theoretical, analytical, and case-study methodologies:

Literature Review: A synthesis of literature review of current research of AI in green infrastructure, smart grid and resource management.

Case Studies: An analysis of global cities such as Singapore, Amsterdam Barcelona, and San Francisco that have adopted and implemented AI-driven green infrastructure systems.

Theoretical Frameworks: Use of systems theory and AI optimization models to analyse the resource management approach to urban ecosystems.

Comparative Analysis: Comparing the sophisticated strategies applied in developed cities with problems and possible solutions in developing urban environments.

Data Analysis: Data analysis to identify the issues of interest, potential problems, and possibilities related to the integration of artificial intelligence-based systems for energy and resource optimization.
Case study-

Case Studies: AI and Green Infrast ructure in Global Cities

Singapore: Leading with Smart Energy Systems

Singapore has positioned itself at the forefront of integrating AI into its urban infrastructure. As a city-state with limited natural resources, Singapore has embraced innovative technologies to create a sustainable and efficient urban environment.

AI in Smart Grids and Renewable Energy Singapore's government, through the Smart Nation initiative, has implemented AI-driven smart grids to enhance energy efficiency. These grids utilize machine learning algorithms to predict energy demand, manage load distribution, and integrate renewable energy sources like solar power. The AI systems forecast energy consumption patterns by analysing historical data, weather conditions, and real-time usage metrics, allowing for optimal energy distribution. One notable project is the deployment of AI-enhanced photovoltaic systems. These systems optimize the use of solar panels by predicting solar irradiance and adjusting the angle and orientation of the panels to maximize energy capture. The AI also manages energy storage systems, deciding when to store or release energy based on demand forecasts, thus reducing reliance on non-renewable energy sources.

Outcomes and Impact The adoption of AI in Singapore's energy systems has led to a significant reduction in energy waste and carbon emissions. According to reports, the integration of smart grids and AI has improved energy efficiency by 20%, contributing to the city's goal of reducing greenhouse gas emissions by 36% by 2030.

Challenges and Future Directions Despite these successes, Singapore faces challenges such as data privacy concerns and the need for continuous technological upgrades. Future plans include expanding AI applications to other sectors, such as water management and transportation, to further enhance sustainability.

Amsterdam: Flood Management through Predictive Modelling Amsterdam, a city known for its intricate canal system, faces unique challenges due to its vulnerability to flooding. The city has leveraged AI technologies to predict and manage water levels, safeguarding both its infrastructure and residents.

AI in Water Management The city utilizes AI-powered predictive models to monitor and manage water levels. These models analyse meteorological data, historical water level records, and real-time inputs from sensors placed throughout the canal system. Machine learning algorithms predict potential flooding scenarios, enabling pre-emptive measures such as adjusting water flow through sluices and pumps.

One key initiative is the AI-driven "Rain Sense" project, which integrates IoT sensors with AI analytics to provide real-time data on rainfall and water levels. This system helps city authorities to make informed decisions on water management, preventing floods and optimizing the use of water resources.

Outcomes and Impact The implementation of AI in water management has significantly reduced the risk of flooding in Amsterdam. The predictive models have enhanced the city's resilience, with a reported 30% improvement in flood prediction accuracy. This has not only protected infrastructure but also minimized economic losses and improved residents' quality of life.

Challenges and Future Directions While the AI systems have proven effective, challenges remain, such as the integration of legacy systems and the need for continuous data updates. Future developments include expanding the AI system to cover more extensive areas and incorporating climate change projections to enhance long-term resilience.

Barcelona: Smart Management for Environmental Control Barcelona has emerged as a leader in using AI to optimize urban management and environmental control. The city's focus on sustainability has led to the adoption of AI technologies to manage energy consumption, reduce emissions, and improve air quality.

AI in Energy and Emission Control Barcelona's smart management systems utilize AI to optimize energy use in buildings and public infrastructure. The city has implemented AI-driven systems to control lighting, heating, and cooling based on real-time data such as occupancy levels, weather conditions, and energy prices. These systems use machine learning algorithms to learn from historical data and continuously improve efficiency.

In addition, AI-powered sensors monitor air quality across the city. These sensors collect data on pollutants, which AI algorithms analyse to predict air quality trends and identify pollution sources. This information allows city authorities to implement targeted measures to reduce emissions, such as adjusting traffic flow or promoting the use of public transport.

Outcomes and Impact The AI initiatives in Barcelona have resulted in a 15% reduction in energy consumption in public buildings and a significant improvement in air quality. The city has

also seen a reduction in greenhouse gas emissions, contributing to its goal of becoming carbon neutral by 2050.

Challenges and Future Directions

Despite these achievements, Barcelona faces challenges in scaling up its AI systems and ensuring data privacy. Future plans include expanding the use of AI in other areas, such as waste management and water conservation, to further enhance urban sustainability.

San Francisco: Revolutionizing Waste Management

San Francisco has long been a pioneer in environmental sustainability, particularly in waste management. The city has adopted AI technologies to improve waste collection, sorting, and recycling processes, aiming to achieve zero waste by 2030.

AI in Waste Management San Francisco's waste management system incorporates AI-driven vision systems to sort waste more efficiently. These systems use machine learning algorithms to identify and separate recyclable materials from non-recyclables. The AI technology improves sorting accuracy and reduces contamination in recycling streams.

Additionally, the city has implemented smart waste bins equipped with sensors that monitor waste levels. These bins communicate with waste collection vehicles, optimizing collection routes and schedules to reduce fuel consumption and emissions. The AI algorithms analyse data from the bins to predict waste generation patterns, allowing for more efficient resource allocation.

Outcomes and Impact The use of AI in waste management has significantly improved recycling rates in San Francisco. The city has achieved an 80% waste diversion rate, one of the highest in the world. The smart waste bins have also led to a 15% reduction in fuel consumption and emissions from waste collection vehicles.

Challenges and Future Directions

Despite the successes, challenges such as the high cost of AI systems and the need for public education on proper waste sorting persist. Future developments include expanding AI applications to other waste management areas, such as composting and hazardous waste disposal, to further reduce landfill contributions.

Comparative Analysis and Lessons Learned

The case studies of Singapore, Amsterdam, Barcelona, and San Francisco illustrate the transformative potential of AI in enhancing green infrastructure and urban sustainability. Each city has leveraged AI to address specific challenges, from energy efficiency and flood management to air quality control and waste management.

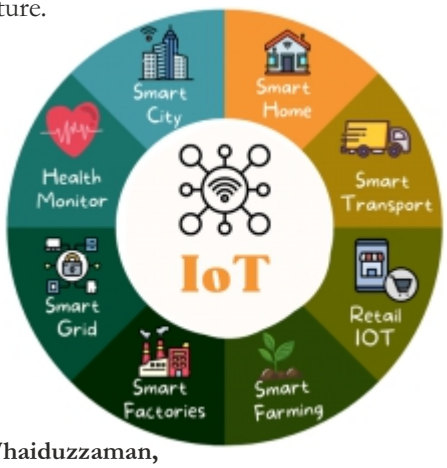
Key Takeaways

- **Customization:** Each city has tailored AI solutions to address its unique challenges, demonstrating the importance of context-specific applications.
- **Collaboration:** Successful AI implementation requires collaboration between governments, private sector partners, and the public.
- **Data Integration:** The effectiveness of AI systems depends on the availability and integration of high-quality data from diverse sources.
- Continuous Improvement: AI systems must be continuously updated and improved to adapt to changing conditions and new challenges.

Challenges and Future Directions

While these case studies highlight the benefits of AI, they also reveal common challenges such as data privacy, integration with legacy systems, and the need for ongoing technological advancements. Future directions include expanding AI applications to new areas, enhancing data security, and fostering greater public engagement in sustainability initiatives. These case studies provide a comprehensive understanding of how AI can be integrated into green infrastructure to create more sustainable and resilient urban environments. By learning from these examples, other cities can adopt and adapt AI technologies to address their specific sustainability challenges. Comparison and Contrast Global City Lessons: Global City Typology: Developed vs. Developing Cities Techn ological Readiness: Internatio nalized developed countries which possess excellent infrastructures and financial backing such as Singapore and the Netherlands open up ways to mandate AI based green systems. However, emerging cities encounter quite a number of problems which are mainly financial and technical. Focus Areas: How, developed cities perform works in the direction of optimization and improvement of the already developed infrastructure and on the other hand, the developing cities concentrate in establishing even the basic systems of green infrastructure to solve the significant problematic areas like waste and water management. Public Participation: While developed cities have higher levels of perceptions about

using AI in the projects and greater population participation, developing cities require technology promotion in the society, and active communication. Conclusion and Advocacy for future research - When blended with green infrastructure, AI can revolutionize how cities solve resource management, enhance their resistance, and address many environmental concerns. Yet, to enable this, there are six major issues that need to be resolved: data protection, ethical issues, and funding. Future research should explore: AI-based digital twin for planning future cities. Adaptation and implementation of circular economy into artificial intelligence in the context of urban environment systems. New generation data management approaches for enhanced transparency, security, and data accessibility to the Samaritan. The focus of this chapter is the call for more effective cooperation between urbanists, decision-makers, and technologists to develop and implement effective, adaptable, and ethical applications of Artificial Intelligence in city planning for the common good. The case studies outlining the application of AI within global urban environments serve as best practice and a precedent for envisioning and constructing climate ready cities of the future.



by Md Whaiduzzaman, Alistair Barros,Moumita Chand , Nov(2023)

Elaboration of Main Points: 1. A case of ai in green infrastructure Green infrastructure includes; parks, wetland, and urban forest to mitigate and address urban sustainability challenges. AI's incorporation helps to supply the immediate reaction of the system and add extra features for making these systems more effective. 2. Use of AI in Resource Management – case of Specific Cities Energy Efficiency: AI integrated smart grid is that which deals with supply of energy, charg ing/discharging battery and the control of Renewable energy sources like solar panels. In the developments of a building some systems control the amount of lighting, heating, cooling depending with the number of people in the building and climatic conditions. Water Management: Intelligent water delivery systems work with AI that accuracy deliver water to irrigation systems which in turn eradicates wastage. Methods of AI technologies are applied to predict the water demand and control the rainwater to avoid flooding in urban settings. Waste Management: Machine learning enhances proper sorting of waste for recycling process. Smart waste bins insert sensors that help manage collection routes and, in the process, avoid much usage of fuel and release of emissions. 3. IoT and Big data in Climate Resilient Cities IoT with data analytics integrated with Artificial Intelligence target environment changes in real-time. Based on the kind of risk, predictive models help anticipate climate risks thus enhancing the coping capacity of cities: heat waves, heavy rainfall, etc. 4. Concerns and Issues While AI offers promising solutions, it also poses challenges: Privacy threats resulting from daily data gathering. Algorithms that can exaggerate the disparities that are present in the society. Some of the limitations include high costs, and technology challenges in particular for the developing world. 5. Future Opportunities New technologies such as smart models make it possible for cities' planners to model the city infrastructures and assess the potential effects of planned changes. Another example is the application of AI in circular economy where waste turns into a new resource seems very promising. The point of view focused in this chapter is based on the concepts of AI, sustainable environment, and urban resilience. The chapter sees AI as a useful element in redesigning urban systems to be more compatible with the environment within the climate change, resource scarcity, and population growth framework. The book analyses how technology in general and AI in particular can be an agent of change towards improving cities' quality and points out ethical, financial and technical constraints that have to be overcome in an effort to produce socially fair and sustainable solutions. The chapter delves into key themes, including: AI in Energy Efficiency: Featuring smart grids that may predict the energy demand and distribution of renewable energy, also improve the energy conservation of buildings in real time. Water Resource Management: Environmental intelligent systems for water management, stormwater and irrigation in urban green spaces. Climate Action and Resilience: Explaining how IoT sensors alongside big data analytics facilitate the ability of cities to evolve and address environmental issues by predicting the outcomes with models,

and applying the dynamics of policy-making. Waste Management: Researching areas of AI application in waste collection routes and recycling procedures as well as policy formation in waste minimization. Challenges and Concerns: Defining challenges like data ownership, use of algorithms in case generation, availability of resources and people's engagement.

Conclusion:

The transformative potential of Artificial Intelligence (AI) in fostering green infrastructure and sustainable urban development is both immense and multifaceted. This chapter has explored how AI technologies can be seamlessly integrated into various aspects of urban resource management, addressing critical issues such as energy efficiency, water conservation, waste management, and climate resilience. While the visions of AI-enabled smart cities are promising, achieving these visions requires overcoming several challenges and embracing collaborative efforts across multiple stakeholders. AI's Role in Urban Resource Management AI's incorporation into urban environments has demonstrated significant potential to optimize resource utilization and promote sustainability. By enhancing the efficiency of green infrastru cture—such as parks, wetlands, and urban forests—AI can improve urban resilience and address environmental challenges. Smart grids, for instance, facilitate energy conservation by predicting energy demands and optimizing the distribution of renewable energy. Similarly, AI-powered systems in buildings can dynamically adjust lighting, heating, and cooling based on occupancy and weather conditions, thereby reducing energy consumption. In water resource management, AI applications have proven valuable in predicting water demands, automating irrigation systems, and preventing urban flooding through precise meteorological data analysis. Waste management also benefits from AI's capabilities, with machine learning models improving waste sorting and recycling processes, and smart sensors optimizing waste collection routes to minimize fuel consumption and emissions. Challenges and Barriers Despite its potential, the adoption of AI in urban planning faces several obstacles. Privacy concerns are paramount, given the extensive data collection required for AI systems to function effectively. The ethical implications of AI algorithms, which can inadvertently reinforce societal disparities, also pose significant challenges. Additionally, the financial and technical resources necessary to implement AI technologies can be prohibitive, especially for developing cities that struggle with basic infrastructure needs. The issue of data privacy and security is particularly critical. As AI systems rely on vast amounts of personal and enviro nmental data, ensuring the protection of this data is essential to maintaining public trust. Furthermore, the opaque nature of some AI algorithms can lead to a lack of transparency, complicating efforts to address biases and ensure fairness in decision-making processes. Best Practices and Global Examples The chapter highlights several best practices from cities around the world, illustrating how AI can enhance green infrastructure and urban sustainability. Singapore's integration of AI in managing intelligent energy systems, Amsterdam's use of predictive models for flood management, and Barcelona's smart environmental control systems showcase the practical applications of AI in addressing urban challenges. These examples underline the importance of adopting a holistic approach to AI implementation, where technological innovation is accompanied by robust governance frameworks, public engagement, and ethical considerations. By learning from these global examples, other cities can tailor their AI strategies to local contexts, ensuring that they address specific urban challenges while promoting sustainability. Future Opportunities and Recommendations Looking ahead, the chapter advocates for continued research and develo pment in AI technologies to further enhance their application in urban environments. The concept of intelligent digital twins, which model urban processes in real-time, offers promising opportunities for city planners to anticipate and mitigate the impacts of urban development. Additionally, the integration of AI into circular economy models can transform waste management by turning waste into valuable resources, promoting sustainability and reducing environ mental impact. To realize the full potential of AI in sustainable urban development, a concerted effort is required from urban planners, policymakers, technologists, and the public. This involves fostering multi-stakeholder collaboration, promoting transparency in AI systems, and ensuring that ethical considerations are at the forefront of AI implementation. In conclusion, while the journey towards AI-enhanced smart cities is fraught with challenges, the potential benefits for urban sustainability and resilience are undeniable. AI

technologies offer innovative solutions to some of the most pressing environmental issues faced by cities today. However, achieving these benefits requires addressing the ethical, financial, and technical barriers that currently hinder widespread adoption. By prioritizing inclusive, transparent, and participatory approaches to AI implementation, cities can build more resilient, efficient, and sustainable urban environments. The chapter underscores the need for proactive best practices, ongoing research, and collaborative governance to harness the full potential of AI in transforming urban landscapes. In doing so, cities can not only meet the challenges of urbanization and climate change but also create vibrant, sustainable communities for future generations.

References:

- Ashton, K. That 'Internet of Things' Thing. RFID J. 2009, 22, 97–114. [Google Scholar]
- Arasteh, H.; Hosseinnezhad, V.; Loia, V.; Tommasetti, A.; Troisi, O.; Shafie-khah, M.; Siano, P. IoT-based smart cities: A survey. In Proceedings of the 2016 IEEE 16th International Conference on Environment and Electrical Engineering (EEEIC), Florence, Italy, 7–10 June 2016; pp. 1–6. [Google Scholar]
- Sun, H.; Yu, H.; Fan, G. Contract-Based Resource Sharing for Time Effective Task Scheduling in Fog-Cloud Environment. IEEE Trans. Netw. Serv. Manag. 2020, 17, 1040–1053. [Google Scholar] [Cross Ref]
- Datta, S.K.; Da Costa, R.P.; Bonnet, C.; Härri, J. One M2M architecture based IoT framework for mobile crowd sensing in smart cities. In Proceedings of the IEEE European Conference on Networks and Communications (EuCNC), Athens, Greece, 27–30 June 2016; pp. 168–173. [Google Scholar]
-
- Rajab, H.; Cinkelr, T. IoT based smart cities. In Proceedings of the International Symposium on Networks, Computers and Communications (ISNCC), Rome, Italy, 19–21 June 2018; pp. 1–4. [Google Scholar]
-
- Khan, A.; Aslam, S.; Aurangzeb, K.; Alhussein, M.; Javaid, N. Multiscale modeling in smart cities: A survey on applications, current trends, and challenges. Sustain. Cities Soc. 2022, 78, 103517. [Google Scholar] [Cross Ref]
- Chatterjee, S.; Kar, A.K.; Gupta, M.P. Success of IoT in smart cities of India: An empirical analysis. Gov. Inf. Q. 2018, 35, 349–361. [Google Scholar] [Cross Ref]
- Park, E.; Del Pobil, A.P.; Kwon, S.J. The role of Internet of Things (IoT) in smart cities: Technology roadmap-oriented approaches. Sustainability 2018, 10, 1388. [Google Scholar] [Cross Ref] [Green Version]
- Abate, F.; Carratù, M.; Liguori, C.; Paciello, V. A low cost smart power meter for IoT. Measurement 2019, 136, 59–66. [Google Scholar] [Cross Ref]
- Barriga, J.K.D.; Romero, C.D.G.; Molano, J.I.R. Proposal of a standard architecture of IOT for Smart Cities. In Proceedings of the International Workshop on Learning Technology for Education Challenges, Hagen, Germany, 25–28 July 2016; Springer: Cham, Switzerland, 2016; pp. 77–89. [Google Scholar]
-
- Rosemann, M.; Becker, J.; Chasin, F. City 5.0. Bus. Inf. Syst. Eng. 2021, 63, 71–77. [Google Scholar] [Cross Ref]
- Sikder, A.K.; Acar, A.; Aksu, H.; Uluagac, A.S.; Akkaya, K.; Conti, M. IoT-enabled smart lighting systems for smart cities. In Proceedings of the IEEE 8th Annual Computing and Communication Workshop and Conference (CCWC), Las Vegas, NV, USA, 8–10 January 2018; pp. 639–645. [Google Scholar]
- Zhao, L.; Wang, J.; Liu, J.; Kato, N. Optimal edge resource allocation in IoT-based smart cities. IEEE Netw. 2019, 33, 30–35. [Google Scholar] [Cross Ref]
- Ghazal, T.M.; Hasan, M.K.; Alshurideh, M.T.; Alzoubi, H.M.; Ahmad, M.; Akbar, S.S.; Al Kurdi, B.; Akour, I.A. Iman IoT for smart cities: Machine learning approaches in smart healthc are—A review. Future Internet 2021, 13, 218. [Google Scholar] [Cross Ref]
- Araujo, V.; Mitra, K.; Saguna, S.; Åhlund, C. Performance evaluation of FIWARE: A cloud-based IoT platform for smart

cities. J. Parallel Distrib. Comput. 2019, 132, 250–261. [Google Scholar] [Cross Ref]

- George, A.M.; George, V.I.; George, M.A. IoT based smart traffic light control system. In Proceedings of the IEEE International Conference on Control, Power, Communication and Computing Technologies (ICCPCCT), Kannur, India, 23–24 March 2018; pp. 148–151. [Google Scholar]
- Ali, G.; Ali, T.; Irfan, M.; Draz, U.; Sohail, M.; Glowacz, A.; Sulowicz, M.; Mielnik, R.; Faheem, Z.B.; Martis, C. IoT based smart parking system using deep long short memory network. Electronics 2020, 9, 1696. [Google Scholar] [Cross Ref]
- Paul, C.; Ganesh, A.; Sunitha, C. An overview of IoT based smart homes. In Proceedings of the IEEE 2nd International Conference on Inventive Systems and Control (ICISC), Coimbatore, India, 19–20 January 2018; pp. 43–46. [Google Scholar]
- Ahmed, Z.; Rawat, A.; Kumari, P. An Anaylsis of Iot Based Smart Cities. Int. J. Eng. Trends Appl. 2021, 8, 30–35. [Google Scholar]
- Marques, P.; Manfroi, D.; Deitos, E.; Cegoni, J.; Castilhos, R.; Rochol, J.; Pignaton, E.; Kunst, R. An IoT-based smart cities infrastructure architecture applied to a waste management scenario. Ad Hoc Netw. 2019, 87, 200–208. [Google Scholar] [Cross Ref]
- Majeed, U.; Khan, L.U.; Yaqoob, I.; Kazmi, S.A.; Salah, K.; Hong, C.S. Blockchain for IoT-based smart cities: Recent advances, require ments, and future challenges. J. Netw. Comput. Appl. 2021, 181, 103007. [Google Scholar] [Cross Ref]
- Gowda, V.D.; Annepu, A.; Ramesha, M.; Kumar, K.P.; Singh, P. Iot enabled smart lighting system for smart cities. J. Phys. Conf. Ser. 2021, 2089, 012037. [Google Scholar] [Cross Ref]
- Simon, J.; Mester, G. Critical overview of the cloud-based internet of things pilot platforms for smart cities. Interdiscip. Descr. Complex Syst. INDECS 2018, 16, 397–407. [Google Scholar] [Cross Ref]
- Anagnostopoulos, T.; Zaslavsky, A.; Kolomvatsos, K.; Medvedev, A.; Amirian, P.; Morley, J.; Hadjieftymiades, S. Challenges and opportunities of waste management in IoT-enabled smart cities: A survey. IEEE Trans. Sustain. Comput. 2017, 2, 275–289. [Google Scholar] [Cross Ref]
- Patti, E.; Acquaviva, A. IoT platform for Smart Cities: Requirements and implem entation case studies. In Procee dings of the IEEE 2nd Inte rnational Forum on Research and Technologies for Society and Industry Leveraging a Better Tomorrow (RTSI), Bologna, Italy, 7–9 September 2016; pp. 1–6. [Google Scholar]
- Al-Sarawi, S.; Anbar, M.; Alieyan, K.; Alzubaidi, M. Internet of Things (IoT) communication protocols. In Proceedings of the IEEE 8th International Confer ence on Information Technology (ICIT), Amman, Jordan, 17–18 May 2017; pp. 685–690. [Google Scholar]
- Adam, M.; Okasha, M.E.; Tawfeeq, O.M.; Margan, M.A.; Nasreldeen, B. Waste management system using IoT. In Proceedings of the IEEE International Conference on Computer, Control, Electrical, and Electronics Engineering (ICCCEEE), Khartoum, Sudan, 12–14 August 2018; pp. 1–4. [Google Scholar]
- Santos, P.M.; Rodrigues, J.G.P.; Cruz, S.B.; Lourenço, T.; d'Orey, P.M.; Luis, Y.; Rocha, C.; Sousa, S.; Crisóstomo, S.; Queirós, C.; et al. PortoLivingLab: An IoT-based sensing platform for smart cities. IEEE Internet Things J. 2018, 5, 523–532. [Google Scholar] [Cross Ref]
- Al-Turjman, F.; Malekloo, A. Smart parking in IoT-enabled cities: A survey. Sustain. Cities Soc. 2019, 49, 101608. [Google Scholar] [Cross Ref]
- Arshad, R.; Zahoor, S.; Shah, M.A.; Wahid, A.; Yu, H. Green IoT: An investigation on energy saving practices for 2020 and beyond. IEEE Access 2017, 5,

15667–15681. [Google Scholar] [Cross Ref]

- Stergiou, C.; Psannis, K.E.; Kim, B.; Gupta, B. Secure integration of IoT and cloud computing. Future Gener. Comput. Syst. 2018, 78, 964–975. [Google Scholar] [Cross Ref]
- Mazumder, A.K.M.M.R.; Uddin, K.M.A.; Arbe, N.; Jahan, L.; Whaiduzzaman, M. Dynamic task scheduling algorithms in cloud computing. In Proceedings of the 3rd International Conference on Electronics, Communication and Aerospace Technology (ICECA), Coimbatore, India, 12–14 June 2019; pp. 1280–1286. [Google Scholar]
- Mukherjee, M.; Shu, L.; Wang, D. Survey of fog computing: Fundamental, network applications, and research challenges. IEEE Commun. Surv. Tutor. 2018, 20, 1826–1857. [Google Scholar] [Cross Ref]
- Vaquero, L.M.; Rodero-Merino, L. Finding your way in the fog: Towards a comprehensive definition of fog computing. ACM SIGCOMM Comput. Commun. Rev. 2014, 44, 27–32. [Google Scholar] [Cross Ref]
- Yu, W.; Liang, F.; He, X.; Hatcher, W.G.; Lu, C.; Lin, J.; Yang, X. A survey on the edge computing for the Internet of Things. IEEE Access 2017, 6, 6900–6919. [Google Scholar] [Cross Ref]
- Wang, X.; Han, Y.; Leung, V.C.M.; Niyato, D.; Yan, X.; Chen, X. Convergence of edge computing and deep learning: A comp rehensive survey. IEEE Commun. Surv. Tutor. 2020, 22, 869–904. [Google Scholar] [Cross Ref] [Green Version]
- Whaiduzzaman, M.; Oliullah, K.; Mahi, M.J.N.; Barros, A. AUASF: An anonymous users authentication scheme for fog-IoT environment. In Proceedings of the 11th International Conference on Computing, Communication and Networking Technologies (ICCCNT), Kharagpur, India, 1–3 July 2020; pp. 1–7. [Google Scholar]
- Whaiduzzaman, M.; Mahi, M.J.N.; Barros, A.; Khalil, M.I.; Fidge, C.; Buyya, R. BFIM: Performance measurement of a blockchain based hierarchical tree layered fog-IoT microservice architecture. IEEE Access 2021, 9, 106655–106674. [Google Scholar]
- Alavi, A.H.; Jiao, P.; Buttlar, W.G.; Lajnef, N. Internet of Things-enabled smart cities: State-of-the-art and future trends. Measurement 2018, 129, 589–606. [Google Scholar]
- Hossen, R.; Whaiduzzaman, M.; Uddin, M.N.; Islam, M.J.; Faruqui, N.; Barros, A.; Sookhak, M.; Mahi, M.J.N. BDPS: An Efficient Spark-Based Big Data Processing Scheme for Cloud Fog-IoT Orchestration. Information 2021, 12, 517. [Google Scholar]
- Al-Fuqaha, A.; Guizani, M.; Mohammadi, M.; Aleshire, M.; Ayyash, M. Internet of things: A survey on enabling technologies, protocols, and applications. IEEE Commun. Surv. Tutor. 2015, 17, 2347–2376. [Google Scholar]
- Hammi, B.; Khatoun, R.; Zeadally, S.; Fayad, A.; Khoukhi, L. IoT technologies<? show [AQ ID= Q1]?> for smart cities. IET Netw. 2018, 7, 1–13. [Google Scholar]
- Zantalis, F.; Koulouras, G.; Karabetsos, S.; Kandris, D. A review of machine learning and IoT in smart transportation. Future Internet 2019, 11, 94. [Google Scholar] [Green Version]
- Hussain, F.; Hussain, R.; Hassan, S.A.; Hossain, E. Machine learning in IoT security: Current solutions and future challenges. IEEE Commun. Surv. Tutor. 2019, 22, 1686–1721. [Google Scholar] [Cross Ref] [Green Version]
- Atitallah, S.B.; Driss, M.; Boulila, W.; Ghézala, H.B. Leveraging Deep Learning and IoT big data analytics to support the smart cities development: Review and future directions. Comput. Sci. Rev. 2020, 38, 100303. [Google Scholar] [Cross Ref]
- Mohan, S.; Thirumalai, C.; Srivastava, G. Effective heart disease prediction using hybrid machine learning techniques. IEEE Access 2019, 7,

81542–81554. [Google Scholar] [Cross Ref]

- Liu, Z.; Yao, C.; Yu, H.; Wu, T. Deep reinforcement learning with its application for lung cancer detection in medical Internet of Things. Future Gener. Comput. Syst. 2019, 97, 1–9. [Google Scholar] [Cross Ref]
- Dourado, C.M.J.M., Jr.; da Silva, S.P.P.; da Nobrega, R.V.M.; Barros, A.C.d.; Reboucas Filho, P.P.; de Albuquerque, V.H.C. Deep learning IoT system for online stroke detection in skull computed tomography images. Comput. Netw. 2019, 152, 25–39. [Google Scholar] [Cross Ref]
- Faruqui, N.; Yousuf, M.A.; Whaiduzzaman, M.; Azad, A.K.M.; Barros, A.; Moni, M.A. LungNet: A hybrid deep-CNN model for lung cancer diagnosis using CT and wearable sensor-based medical IoT data. Comput. Biol. Med. 2021, 139, 104961. [Google Scholar]
- Calabrese, M.; Cimmino, M.; Fiume, F.; Manfrin, M.; Romeo, L.; Ceccacci, S.; Paolanti, M.; Toscano, G.; Ciandrini, G.; Carrotta, A.; et al. SOPHIA: An event-based IoT and machine learning architecture for predictive maintenance in industry 4.0. Information 2020, 11, 202. [Google Scholar] [Cross Ref] [Green Version]