**Global Scientific** JOURNALS

# An Assessment of the Role of Artificial Intelligence (AI) and Green Technology in the Development of Smart and Sustainable Cities

T. L Nxumalo[1],  M Tembo[2] and E. M Mwanaumo[3]

1. *University of Zambia, School of Engineering Department of Civil and Environmental Engineering*
2. *University of Zambia, School of Engineering Department of Civil and Environmental Engineering*
3. *Department of Civil Engineering, College of Science, Engineering and Technology, University of South Africa*

**Abstract:** *Artificial intelligence (AI) and Green technology are new, powerful concepts with a wide range of capabilities, which are currently being embroiled by most cities nowadays. The increased popularity of AI and Green technology for smart and sustainable cities is rather limited compared to other sectors. Moreover, despite AI and green Technology being slowly implemented and applied in most cities, there are currently limited review studies investigating the challenges and opportunities that come with adopting AI and Green technology for smart and sustainable cities. This study aims to reduce this gap by identifying the adoption challenges of AI and green Technology, the opportunities offered, and the challenges encountered for smart and sustainable cities. To achieve the aim, an existing theoretical literature review, through which a comprehensive office survey was conducted in scientific references, reports, studies, research, etc. The scientific journals reviewed included the Role of Artificial Intelligence (AI),  Green Technology, and smart and Sustainable cities. The results of the literature review reveal that (a) the role of Artificial Intelligence (AI) and Green Technology in developing environmentally sustainable green towns can be viable, (b) AI is rapidly becoming a critical smart city element that helps achieve necessary efficiencies and automation to deliver urban infrastructures, services, amenities, and urban densification; (b) the major opportunity in adopting AI and Green technology is the reduction of waste and recycling of building construction waste materials, using ecological low-energy and affordable building materials, houses be healthy, durable, safe, and secure, and (d) the biggest challenge in adopting  AI and Green Technology for smart and sustainable cities is that machine learning AI needs a lot of data, and data processing and data storage use energy, which impacts the environment and climate change, which is widely regarded as one of the biggest and most threatening global challenges facing humanity—if not the worst. The study's findings inform a range of stakeholders in the sustainability field concerning the opportunities and challenges of AI and Green Technology adaptability and help increase the knowledge of AI and Green Technology practices.*

**Keywords:** *Artificial intelligence (AI), Green Technology, Smart and Sustainable Cities, Challenges of AI and Green Technology, and Opportunities of AI and Green Technology*

## 1.  INTRODUCTION

Cities face increasing global environmental challenges, such as climate change, air pollution, resource depletion, and waste generation. These challenges hamper the progress toward sustainability and affect the quality of life for the urban population (WEF, 2020). Cities utilize digital technologies to make infrastructure services more efficient and reactive, reducing resource consumption, increasing environmental quality, and reducing carbon emissions (Evans et al., 2019). AI can help analyse large amounts of data from various sources, such as sensors, satellites, drones, and social media, to provide insights and solutions for urban planning, management, and governance (Alkhatib, 2020). Artificial Intelligence (AI) can be crucial in creating smart and sustainable cities (Gutiérrez et al., 2021)

According to the WEF (2020), there is a need to find innovative ways to create smart and sustainable cities that can reduce their environmental impact and enhance their social and economic performance. This research answers how artificial intelligence, with the help of green technology, influences the development of smart cities. The study explores how AI and Green Technology can contribute to developing smart and sustainable towns. The paper reviews the concepts of smart and sustainable towns and their importance in the modern era. Further, the study assesses the role of AI and Green Technology in enhancing the efficiency, resilience, inclusion, and participation of smart and sustainable towns. In addition, the paper identifies the challenges and opportunities of implementing AI and Green Technology in smart and sustainable towns. The study provides recommendations and best practices for developing data-driven sustainable towns. This research helps academics and government officials better understand the interaction between artificial intelligence and green technology to create smart cities better.

## 2. LITERATURE REVIEW

Technology adoption to ensure an easy and efficient lifestyle is not new. Humanity has been integrating technology into daily processes for ages to achieve some level of automation and decision-making (Ahada et al., 2020)

### 2.1 Effects of AI and green technology on sustainable cities

Carley & Spapens (2010) define green innovations as entrepreneurial activities involving the design phase of the product and the integrated management of its life cycle, which contributes to the ecological modernization of the economy. Khatry et al. (2021) stated that green technology could help implement renewable energy sources, energy-efficient buildings, low-carbon transportation, waste management, and circular economy practices. AI and green technology can optimize, enhance, and maintain the performance of smart and sustainable cities and achieve the desired sustainability outcomes (Gutiérrez et al., 2021; Khatry et al., 2021). These concerts constitute an implementation of the widespread use of new products, technologies, and infrastructure equipment, whose purpose is to protect the elements of the environment: air, water, soil, landscape, flora, and fauna, as well as a human related to the negative influence of economic activity (Białoń, 2010). Wegrzyn (2013) links green innovation with environmental sensitivity and ecological awareness.

### 2.2 The concepts of smart and sustainable cities

Nam & Pardo (2011) mentioned that there are several definitions put forward for the "smart city" concept; these definitions come from many different disciplines (i.e., ICT and urban planning) and communities (i.e., academic and industry). Further, Höjer & Wangel (2015) describe a sustainable smart city as one in which every aspect of the smart city ecosystem, like infrastructure, policies, governance, feedback, control, and management. Ahada et al. (2020) mentioned that a smart city ecosystem provides a means to deliver personal, social, cultural, economic, environmental, and physiological well-being to the inhabitants to improve the "Quality of Life." Hence, the concept of smart and sustainable cities is described in the table.

**Table 1** The Concept of Smart and Sustainable Cities

| Class | Concept | Author |
|---|---|---|
| Energy and environment: | Sustainable growth is created by technology, and cities make better use of resources from electronic sensors that monitor leakages, as | Fedorova et al. (2019) |

| | well as gamification and behavioral economics to support citizens in conducting considerate decisions on resource utilization | |
|---|---|---|
| Economy | The economy will be affected by digitization and disruptive technologies, changing the needs of several jobs. Smart cities create strategies to adopt future jobs that will power Industry 4.0 and beyond. | Lasi et al. (2014) |
| Safety and Security | As criminals will use technology to commit advanced crimes, public safety, and security authorities will also use technology for crime prevention by assessing multiple streams of social and crowdsourced information, including super-resolution images. | Dong et al. (2019) |
| Health and living | The lives of citizens are enhanced with technology and connectivity. Connected communities are achieved with smart buildings. Enhanced social programs and innovative healthcare sector are data-driven | Taha et al. (2018) |
| Mobility: | The integrated mobility systems include autonomous vehicles and shared mobility services achieved with the Internet of Things (IoTs). The concept of IoTs occurs when devices communicate with other devices on behalf of people and will dominate the future of Internet communications. | Guerrero-Ibanez & Zeadally (2015) |
| Education and government: | Technological advancement will aid government procedures and give a seamless experience to businesses. Smart cities use analytics to assist authorities in creating insight-driven policies, monitor performance and outcomes, allow constituent engagement, and enhance government efficiency. | Hoel & Mason (2018) |

Source: Made by the authors

Smart, sustainable cities are a common framework or joint vision for elaborating new collaborations, business models, and urban development methods (Höjer & Wangel, 2015). Ahada et al. (2020) found that these developments extend from using clean, reusable codes, environment-friendly and recyclable raw materials, and optimal energy consumption in devices, systems, and sub-systems. The most critical goal in a sustainable smart city is to provide a mechanism for fulfilling the requirements of the present and future generation inhabitants. For smart cities to be sustainable, cities need to implement intelligent solutions enabled by innovative technology. According to Vito Albino et al. (2015), smart technology solutions need "smart city initiatives" from communities. Smart city initiatives involve every stakeholder in collaboration and partnership efforts (Vanolo, 2014)

### 2.3 The Role of AI and Green Technology

According to Cugurullo (2020), cities are currently developed under the smart city banner. Witte (2016) mentioned that AI is causing the workforce to be evolving. AIs practice learning, intended as gaining knowledge, directly by sensing the environment through, for instance, cameras and microphones and indirectly using large data sets (Cugurullo, 2020). As demonstrated by Nadikattu (2016), AI has made people's lives increasingly more productive day after day by

powering multiple services and programs, which will help people do daily things like establishing a connection with friends using email applications or services for ride-sharing.

The application of green technology and environmental sustainability in cities necessitates the elimination of emissions on the planet, preserving natural resources, and the safeguarding natural habitats by effectively utilizing resources. Smart cities must integrate green technologies and solutions to tackle the issues of clean water shortage, depleting air quality, diminishing natural resource reserves, and ecological imbalance (Tanguay et al., 2010)

### 2.4 The challenges and opportunities of implementing AI and Green Technology

There is a great need to implement the concept of smart cities. These will create a sustainable and resilient smart city by understanding the effects of AI and green technology on biodiversity and urban ecology and then integrating this knowledge into the smart city's planning, development, and maintenance (McDonnell & Hahs, 2013)

### 2.4.1 *Challenges of implementing AI and Green Technology*

Witte (2016) explains that AI is causing the workforce to evolve, but there are too many job losses for machines; yet, the challenge for the human race is to discover their passion along with newer responsibilities, which require unique social abilities. Ahada et al. (2020) explain that there is no standard guideline on how to dispose of old devices and systems in an environment-friendly manner due to the implementation of AI. It is worse in semi-urban and rural areas because they are unaware of the harmful environmental and health effects of the e-waste dumped in landfills, open spaces, and oceans.

Nadikattu (2016) mentioned that 82.6 percent of the e-waste that is undocumented, traded, and dumped in a manner that is not environmentally sound is dumped in the waste bins of the European Union due to Infrastructure damage which is adversely affecting the complete smart city ecosystem when natural disasters like floods, earthquakes, and landslides hit a particular city (Ahada, et al., 2020). The unavoidable changes in the weather also pose critical threats to the smart city ecosystem because global warming is at its peak. (Ahada, et al., 2020). As mentioned by Hunter & Hewson (2020), due to pollution, The most catastrophic threats humanity is facing today include chemical pollution of the earth's system, including the atmosphere and oceans; the collapse of ecosystems and loss of biodiversity; the decline of natural resources, particularly water; and global warming and human-induced climate change.

Gavrilescu (2010) states that environmental biotechnology is an emerging innovation regarding ecological insurance since quick industrialization, urbanization, and advancements have undermined clean climate and exhausted standard assets. Due to rapid industrialization and population growth, various synthetic materials like heavy metals, pesticides, insecticides, steroids, dyes, and other organic materials are added to the environment, contaminating it. This contamination leads to cause various fatal diseases like human cancer (Bradu, et al., 2022). Further, Non-biodegradable plastic waste has become a significant pollutant in our water bodies like the rivers and seas. About 8 million tonnes of plastic waste is dumped each year. If this discharge pattern continues, we will have more plastic than fish by 2050 (Tu, et al., 2021).

A study by Bradu et al. (2022) discovered that nowadays, more and more engineers are focusing on the sustainable production of devices and products to shift the mindset from carbon-associated growth and clean up after pollution caused to ways of tackling the by-products by either recycling them or destroying them in sustainable processes before starting the

manufacturing again. However, not everyone and every society and community on this planet is equally vulnerable to climate change: some are more vulnerable than others. For example, those living in areas susceptible to flooding (e.g., a specific Pacific island population) or regions with prolonged droughts are more at risk, and older people suffer more from heat.

### 2.4.2 Opportunities for Implementing AI and Green Technology

AI improves the workplace's efficiency by augmenting humankind's work. AI is taking over hazardous tasks by freeing up manual labour so that people can apply the same consistency in other jobs that are better for them. These involve understanding and resourcefulness. People will work in more engaging posts, thus increasing job satisfaction and happiness (Nadikattu, 2016). Ahada et al. (2020) found that legacy systems and devices are becoming outdated, with new devices and technologies increasingly developed.

Further, Nadikattu (2016) highlighted that society will be on its way to gaining numerous productive hours with the introduction of AI. Eliminating human or natural encroachments on agricultural lands and respect for ecosystems and biological diversity (United Nations, Arab Report for Sustainable Development, 2020). The flexibility of moving between cities through safe, clean, convenient, time- and energy-efficient, and affordable transport for everyone (United Nation, Global Mobility Report 2017). Golubchikov & Badyina (2012) conclude that there will be a reduction of waste and recycling of building construction waste materials, using ecological, low-energy, and affordable building materials, houses will be healthy, durable, safe, and secure if the application of AI and green technology is rolled out very well.

Białoń (2010) states that when implemented well, AI will protect the environment's elements: air, water, soil, landscape, flora, and fauna, as well as a human related to the negative influence of economic activity. According to the UNDP (Driving Sustainable Development Biodiversity and Ecosystems Global Framework 2012-2020), implementing AI and green technology will provide that reservation of wilderness and biological diversity of area ecosystems. The UNDP (Sustainable Development Goals - Goal 11) adds that it will provide enough green and open spaces that are safe and accessible, in particular for children and women, older persons, and persons with disabilities.

## 3. METHODOLOGY

### 3.1 Research design

The study is a theoretical examination of literature relating to the role of Artificial Intelligence (AI) and Green Technology in developing smart and sustainable towns. Moreover, the study adopted a qualitative approach to gather and assess relevant information on the effect of AI and green technology on sustainable cities, the concepts of smart and sustainable cities, the role of AI and Green Technology, and the challenges and opportunities of implementing AI and Green Technology. Qualitative research design concerns individuals" own accounts of their attitudes, motivations, and behavior (Mashwama et al., 2019). Qualitative research offers richly descriptive reports of individuals" perceptions, attitudes, beliefs, views and feelings, the meanings and interpretations given to events and things, as well as their behavior. It further provides perceptions of the social components of the procedures among agencies (Mashwama et al., 2018).

### 3.2 Data collection

The research adopts the existing theoretical literature review, through which a comprehensive office survey was conducted in scientific references, reports, studies, research, etc. These are scientific journals or international institutions with weight and close connection with the subject of the research to reach an accurate definition of the Role of Artificial Intelligence (AI) and Green Technology in the Development of Smart and Sustainable Cities, various dimensions, indications, and strategies for reaching those (Hossm et al., 2021).

### 3.3 Data analysis

Hakim (1982) defines secondary analysis as "any further analysis of an existing dataset which presents interpretations, conclusions or knowledge additional to, or different from, those presented in the beginning." This is done in an investigative manner to learn what is already known and what remains to be learned about a topic through reviewing secondary sources and investigating what others have previously conducted in the specified area of interest. This study has adopted secondary data analysis because it offers methodological benefits and contributes to library and information science research by generating new knowledge.

## 4. FINDINGS

From the literature review, we have deduced that the role of Artificial Intelligence (AI) and Green Technology in developing environmentally sustainable green towns can be viable. According to Panchal & Awasthi (2017), the future of smart cities should be prioritized to solve problems like proper use of energy and interaction between elements of smart city systems. Smart cities must progress in comprehensive renewable energy strategies through alternative sources such as photovoltaic panels, thermal collectors, wind turbines, biomass, and geothermal energy to meet energy demand Yigitcanlar et al. (2021). Martos et al. (2016) added that new innovative waste management and decomposition mechanisms have been developed in municipal solid waste landfill facilities to recycle plastic, glass, biomass, and hazardous waste to minimize the environmental impact of the waste generated in a smart city.

In summary, Neirotti et al. (2014) present a slightly different approach based on a conceptual framework comprising several application domains that they see as classifying a smart city, as illustrated by Fig 1.0 below.
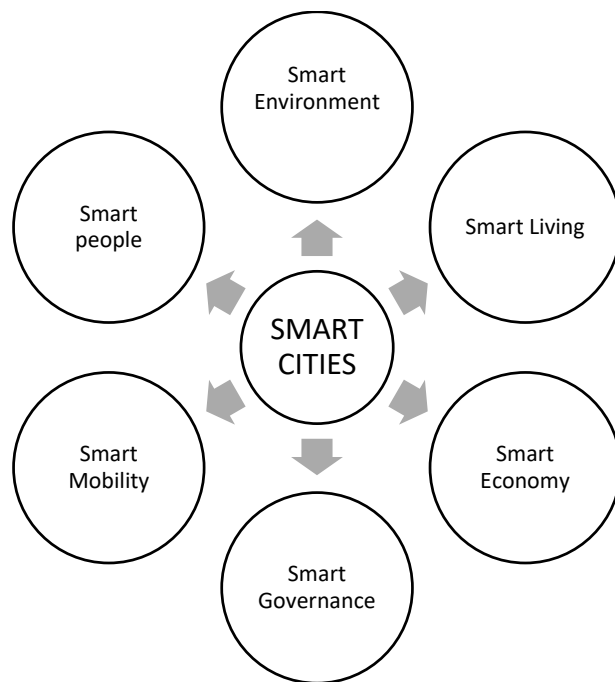
**Fig. 1:** The Concerp of Smart City Domains (Giffinger et al. (2007)

Furthermore, Ullah et al. (2020) state that AI is rapidly becoming a critical smart city element that helps achieve necessary efficiencies and automation to deliver urban infrastructures, services, amenities, and urban densification. Urban densification is a sustainable city strategy. A dense city is essentially a sustainable city since most of the residents are typically nearer to the centralized services of a community. Integrating AI is also helpful because it helps provide a real-time report(s) on traffic accidents or predict traffic conditions. In other words, AI application for developing Intelligent Transport Systems is essential because it can solve many of the smart city's problems like traffic congestion, overcrowding, and environmental degradation (Agarwal et al., 2015). The table summarizes the application of AI in green technology from the literature.

**Table 2** Application of AI to Green Technology

| AI Application | Description | Author |
|---|---|---|
| Intelligent infrastructure | Electronic devices, software-driven systems, or other advanced technologies in the form of AI, which perceive the building environment and take action to improve/ optimize the system performance | (Adio-Moses & Asaolu, 2016). |
| Intelligent Transport System | Resolving complex transport system problems at a faster and more efficient scale (e.g., huge amount of data processing). | Agarwal et al. (2015) |
| Intelligent energy control in buildings | Management and control of energy consumption in buildings and in the public space. | Giffinger et al. (2007) |
| Intelligent Climate Change Control | Methods that aim to alter the climate system to counter climate change deliberately, termed geoengineering, have been proposed. | Intergovernmental Panel on Climate Change: Climate Change (2013) |
| Intelligent Waste disposal | Automatic waste selection via ubiquitous devices on products | Stone et al.(2016) |

Source: Made by the authors

The literature shows there are high chances of underlying infrastructure damage and adversely affecting the complete smart city ecosystem when natural disasters like floods, earthquakes, and landslides hit a particular city. There is no effective management of greenhouse gas emissions. Table 3.0 from the literature review explains the challenges of implementing AI and green technology.

**Table 3** Challenges of Implementing AI and Green Technology

| Author | Challenges |
|---|---|
| (Gavrilescu, 2010) | Environmental biotechnology is an emerging innovation regarding ecological insurance since quick industrialization, urbanization, and advancements have undermined a clean climate and exhausted standard assets. |
| (Coeckelbergh, 2021) | Machine learning AI needs a lot of data, and data processing and data storage use energy, which impacts the environment and climate change, which is widely regarded as one of the biggest and most threatening global challenges facing humanity—if not the worst. Global temperatures keep rising, extreme weather events exist, and many species face extinction. |
| (Bradu, et al., 2022) | Due to rapid industrialization and population growth, various synthetic materials like heavy metals, pesticides, insecticides, steroids, dyes, and other organic materials are added to the environment, contaminating it. This contamination leads to various fatal diseases like cancer in humans. |
| (Tu, et al., 2021) | Non-biodegradable plastic waste has become a significant pollutant in our water bodies, like the rivers and seas. About 8 million tonnes of plastic waste is dumped each year. If this discharge pattern continues, we will have more plastic than fish by 2050 |
| (Bradu, et al., 2022) | Nowadays, more and more engineers are focusing on the sustainable production of devices and products to shift the mindset from carbon-associated growth and clean up after pollution caused to tackling the by-products by either recycling them or destroying them in sustainable processes before starting the manufacturing again. |
| (Coeckelbergh, 2021) | Not everyone and every society and community on this planet is equally vulnerable to climate change; some are more vulnerable than others. For example, those living in areas susceptible to flooding (e.g., a specific Pacific island population) or regions with prolonged droughts are more at risk, and older people suffer more from heat. |

Source: Made by the authors

According to Lai et al. (2020), a smart city is an ambitious and crucial transformation of many cities worldwide. A smart city consists of the development and application of novel technologies. There is a need for standardized uniform engineering or technical criteria, methods, processes, and practices (Voda, 2018). The literature review table 4 summarizes various initiatives adopted for opportunities to implement Green Technology from the literature review.

**Table 4** Opportunities of Implementing AI and Green Technology

| Author | Opportunities |
|---|---|
| (Białoń 2010) | Protect the elements of the environment: air, water, soil, landscape, flora, and fauna, as well as a human related to the negative influence of economic activity. |
| UNDP (Driving Sustainable Development Biodiversity and Ecosystems Global Framework 2012-2020) | Preservation of wilderness and biological diversity of area ecosystems |
| UNDP (Sustainable Development Goals - Goal 11) | Provide enough green and open spaces that are safe and accessible, in particular for children and women, older persons, and persons with disabilities. |

| United Nations, Arab Report for Sustainable Development (2020) | Eliminating human or natural Encroachments on agricultural lands and respect for ecosystems and biological diversity |
|---|---|
| United Nation, Global Mobility Report (2017) | The flexibility of moving between cities through Safe, clean, convenient, time- and energy-efficient, and affordable transport for everyone. |
| Golubchikov & Badyina (2012). | Reduction of waste and recycling of building construction waste materials, using ecological low-energy and affordable building materials, houses be healthy, durable, safe, and secure. |

Source: Made by the authors

## 5. DISCUSSION

According to (Gavrilescu, 2010), the most challenging implementation of AI and green technology for smart and sustainable cities is the environmental biotechnology issue, an emerging innovation regarding ecological insurance since quick industrialization, urbanization, and advancements have undermined a clean climate and exhausted standard assets. Bradu et al. (2022) add that due to rapid industrialization and population growth, various synthetic materials like heavy metals, pesticides, insecticides, steroids, dyes, and other organic materials are added to the environment, contaminating it. This contamination leads to various fatal diseases like cancer in humans. Coeckelbergh (2021) mentioned that not everyone and every society and community on this planet is equally vulnerable to climate change; some are more vulnerable than others. For example, those living in areas susceptible to flooding (e.g., a specific Pacific island population) or regions with prolonged droughts are more at risk, and older people suffer more from heat. However, these findings are in disagreement with the UNDP (Sustainable Development Goals - Goal 11), which states that smart and sustainable city implementation will provide enough green and open spaces that are safe and accessible, in particular for children and women, older persons, and persons with disabilities. The United Nations, Arab Report for Sustainable Development (2020) adds that it will help eliminate human or natural encroachments on agricultural lands and respect for ecosystems and biological diversity.

The study of Bradu et al. (2022) found that nowadays, more and more engineers are focusing on the sustainable production of devices and products to shift the mindset from carbon-associated growth and clean up after pollution caused to tackling the by-products by either recycling them or destroying them in sustainable processes before starting the manufacturing again. Tu et al. (2021) add that non-biodegradable plastic waste has become a significant pollutant in our water bodies, like the rivers and seas. About 8 million tonnes of plastic waste is dumped each year. If this discharge pattern continues, we will have more plastic than fish by 2050. These findings are in disagreement with Białoń (2010), who mentioned that the implementation of AI and green technology in smart and sustainable cities would protect the elements of the environment: air, water, soil, landscape, flora, and fauna, as well as a human related to the negative influence of economic activity. Golubchikov & Badyina (2012) add that these will also help reduce waste and recycle construction waste materials, using ecological, low-energy, and affordable building materials, and houses be healthy, durable, safe, and secure.

Coeckelbergh (2021) concludes that machine learning AI needs a lot of data, and data processing and data storage use energy, which impacts the environment and climate change, which is widely regarded as one of the biggest and most threatening global challenges facing humanity—if not the worst. Global temperatures keep rising, extreme weather events exist, and many species face

extinction. However, the UNDP (Driving Sustainable Development Biodiversity and Ecosystems Global Framework 2012-2020 states that smart and sustainable cities will help preserve the wilderness and biological diversity of area ecosystems. The United Nations Global Mobility Report (2017) further found that moving between cities will be flexible through Safe, clean, convenient, time- and energy-efficient, and affordable transport for everyone.

The findings found that the future trends of AI and Green technology for smart and sustainable cities are established around five central themes of better awareness and acceptance of these AI and green technologies:

1. Intelligent infrastructure - Electronic devices, software-driven systems, or other advanced technologies in AI that perceive the building environment and take action to improve/ optimize the system performance (Adio-Moses & Asaolu, 2016).
2. Intelligent Transport System - Resolving complex transport system problems at a faster and more efficient scale (e.g., huge amount of data processing)(Agarwal et al., 2015).
3. Intelligent energy control in buildings - Management and control of energy consumption in buildings and public space (Giffinger et al., (2007)
4. Intelligent Climate Change Control - Methods that aim to alter the climate system to counter climate change deliberately, termed geoengineering, have been proposed. (Intergovernmental Panel on Climate Change: Climate Change, 2013)
5. Intelligent Waste disposal - Automatic waste selection via ubiquitous devices on products (Stone et al., 2016)

## 6. CONCLUSION

AI and Green technology, with their core smart properties, present a new vision for future Smart and Sustainable Towns. Given the fact that implementation of AI and Green Technology is in the early days of their development, there are technical challenges, e.g., infrastructure damage, which led to natural disasters like floods, earthquakes, landslides, pollution, global warming and human-induced climate change making AI and Green technology yet to be widely applicable in current Smart and Sustainable Cities. In addition to the hurdles, there are other technical challenges, particularly the acceptance of AI, organization readiness, cultural changes, and the new cost to be overcome.

Nevertheless, by overcoming these challenges, it is envisaged that adopting AI and Green technology will gradually supersede the challenges and become the basic elements of smart and sustainable towns in the future, thus enabling safer, greener, more efficient, and more effective cities. The development of capabilities will be a key aspect of the implementation and success of AI and Green technology in conversion efforts. It must be recognized that AI and Green Technology transformations are not evolutionary but rather systemic, i.e., everything must change.

The current study's findings can serve as a reference for decision-makers who aim to reduce the gaps in AI and Green technology implementation and reach ideal levels. Such knowledge can help all stakeholders to understand the benefits of AI and Green Technology implementation performance and devise strategies for improvement. The empirical example demonstrates the substantial flexibility of moving between towns through safe, clean, convenient, time- and energy-efficient, affordable transport for everyone. At the same time, the individual stays in a clean, unpolluted environment with energy-saving green buildings.

However, an additional limitation exists: AI and Green Technology implementation is sophisticated and requires many financial resources. This can lead to some time in implementing AI and Green Technology, potentially affecting the final implementation and adoption. Therefore, individuals must be patient in implementing AI and Green Technology for smart and sustainable town efforts and realize that benefits will take time to be thoroughly enjoyed. However, our conclusions are exclusively based on assessing the role of AI and Green Technology in the development of Smart and Sustainable Cities, thus exercising caution in interpreting the results and generalizing the conclusion. Future studies can refer to barriers and the level of awareness of AI and Green Technology in developing Smart and Sustainable Towns and draw accurate comparisons.

## Recommendations

Considering the identified challenges and opportunities to the successful implementation of AI and Green Technology for the development of smart and sustainable cities, the following recommendations are made:

1. Future studies could compare other contexts of AI and Green Technology, such as the Principles of AI and Green Technology for sustainable cities.
2. Studies could launch a general survey covering various experience levels of industrial practitioners and compare perceptions of the respondents based on their professions regarding AI and Green technology for smart and sustainable cities.
3. Lastly, studies could consider the elements and case analysis of AI models and Green Technology designs for sustainable cities.

## Practical Implications

The AI and Green Technology industry is experiencing explosive exposure to new concepts and technologies. The new approaches will bring a new conceptualization of AI and Green Technology in the future. This study could provide valuable information to scholars and practitioners in AI and Green technology-associated areas for smart, sustainable cities.

1. To the researchers, this study could facilitate them to discover the relevant literature on AI and Green Technology effectively.
2. To Industry practitioners, this study could help them to effectively identify the latest knowledge in the field of AI and Green Technology for the development of smart and sustainable cities, then enhance new products to expand their future market.
3. This study also expanded the AI and Green Technology methodology for smart, sustainable cities-related research.

**REFERENCES**

1. Ahada, M. A., Paivab S, Tripathi G, Feroza N (2020) Enabling technologies and sustainable smart cities  Sustainable Cities and Society 61 102301.

2. Adio-Moses, D. & Asaolu, O. S. (2016). Artificial Intelligence for Sustainable Development of Intelligent Buildings, In Proceedings of the 9th CIDB Postgraduate Conference, University of Cape Town, South Africa.

3. Agarwal, P. K., Gurjar, J., Agarwal, A. K. & Birla, R. (2015). Application of artificial intelligence for the development of intelligent transport systems in smart cities. Journal of Traffic and Transportation Engineering, 1(1), 20-30.

4. Alkhatib, A., (2020). A vision to build AI-powered Smart and Sustainable Cities: Are we there yet? AI for Good.

5. Batty, M. Artificial intelligence and smart cities (2018) Environ. Plan. B Urban. Anal. City Science.

6. Białoń L., (2010) Zarządzanie działalnością innowacyjną, Placet, Warszawa, p. 25.

7. Bradu, P., Biswas, A., Nair, C., Sreevalsakumar, S., Patil, M., Kannampuzha, S., Mukherjee, A.G., Wanjari, U.R., Renu, K., Vellingiri, B. and Gopalakrishnan, A.V., 2022. Recent advances in green technology and Industrial Revolution 4.0 for a sustainable future. Environmental Science and Pollution Research, pp.1-32.

8. Calvillo, C. F., Sánchez-Miralles, A., & Villar, J. (2016). Energy management and planning in smart cities. Renewable and Sustainable Energy Reviews, 55, 273–287.

9. Carley M. & Spapens P., (2010). Dzielenie się światem, Wyd. Instytutu na rzecz Ekorozwoju, Białystok–Warszawa.

10. Charmes, E., & Keil, R. (2015). The politics of post-suburban densification in Canada and France. International Journal of Urban and Regional Research, 39(3), 581–602.

11. Coeckelbergh, M., (2021). AI for climate: freedom, justice, and other ethical and political challenges. AI and Ethics, 1(1), pp.67-72.

12. Cugurullo F (2020) Urban Artificial Intelligence: From Automation to Autonomy in the Smart City. Front. Sustain. Cities 2:38.doi: 10.3389/frsc.00038

13. Dong, Z.; Lai, C.S.; He, Y.; Qi, D.; Duan, S. (2019) Hybrid dual-complementary metal–oxide semiconductor/memristor synapse-based neural network with its applications in image super resolution. IET Circuits Devices Syst. 2019, 13, 1241–1248

14. European Commission: Digital Agenda for Europe—About Smart Cities (2013). https://ec.europa.eu/digital-agenda/en/about-smart-cities -(Assessed 28 August 2023).

15. Evans, J.; Karvonen, A.; Luque-Ayala, A.; Martin, C.; McCormick, K.; Raven, R.; Palgan, Y.V (2019) Smart and sustainable cities? Pipedreams, practicalities and possibilities. Local Environment.

16. Falconer, G., & Mitchell, S. (2012). Smart city framework. Cisco Internet Business Solutions Group (IBSG)1–11.

17. Fedorova, E.; Caló, A.; Pongrácz, E. (2019) Balancing Socio-Efficiency and Resilience of Energy Provisioning on a Regional Level, Case Oulun Energia in Finland. Clean Technol. 2019, 1, 273–293.

18. Gavrilescu M (2010) Environmental biotechnology: achievements, opportunities and challenges. Dyn Biochem Process Biotechnol Mol Biol 4(1):1–36

19. Giffinger, R., Fertner, C., Kramar, H., Kalasek, R., Pichler-Milanovic, N. and Meijers, EJ, 2007. Smart cities. Ranking of European medium-sized cities. Final Report.

20. Golubchikov, O. and Badyina, A.,(2012). Sustainable housing for sustainable cities: a policy framework for developing countries. Nairobi, Kenya: UN-HABITAT.

21. Guerrero-Ibanez, J.A.; Zeadally, S. (2015) ; Contreras-Castillo, J. Integration challenges of intelligent transportation systems with connected vehicle, cloud computing, and internet of things technologies. IEEE Wirel. Commun. 2015, 22, 122–128

22. Gutiérrez, J., García-Palomares, J.C., Romanillos, G. and Salas-Olmedo, M.H., 2021. Green Artificial Intelligence: Towards an Efficient, Sustainable and Equitable Technology for Smart Cities and Futures. Sustainability, 13(16), p.8952.

23. Hakim, C. (1982). Secondary analysis in social research: A guide to data sources and method examples. London, UK: George Allen & Uwin

24. Hoel, T.; Mason, J.(2018) Standards for smart education–towards a development framework. Smart Learn. Environ. 2018, 5, 3

25. Höjer, M., & Wangel, J. (2015). Smart sustainable cities: Definition and challenges. ICT Innovations for Sustainability. Cham: Springer333–349.

26. Hossm, Kotba., Ahmed, El-Menshwya., Toka H. Beah (2021) Sustainable Cities The Egyptian International Journal of Engineering Sciences and Technology, Vol 34 page 38-44

27. Khan, Y. Z. (2015). Smart city "A dream to be true". International Journal of Linguistics and Computational Applications (IJLCA), 2(1), 1–5.

28. Khatry, S., Kwartler, E., Firth-Butterfield, K. and Caine, M., (2021). What would it take to make AI 'greener'? World Economic Forum. Available at:

https://www.weforum.org/agenda/2021/09/make-ai-greener-climate-solution-cop26-technology/ (Accessed 14 August 2023).

29. Kramers, A., Wangel, J., Johansson, S., Höjer, M., Finnveden, G., Brandt, N. (2013) Towards a comprehensive system of methodological considerations for cities' climate targets. Energy Policy 62, 1276–1287.

30. Lasi, H.; Fettke, P.; Kemper, H.-G.; Feld, T.; Hoffmann, M. (2014) Industry 4.0. Business Information Systems Engineering 2014, 6, 239–242

31. Lai, C.S., Jia, Y., Dong, Z., Wang, D., Tao, Y., Lai, Q.H., Wong, R.T., Zobaa, A.F., Wu, R. and Lai, L.L., 2020. A review of technical standards for smart cities. Clean Technologies, 2(3), pp.290-310.

32. Martos, A., Pacheco-Torres, R., Ordóñez, J., & Jadraque-Gago, E. (2016). Towards successful environmental performance of sustainable cities: Intervening sectors. A review. Renewable and Sustainable Energy Reviews, 57, 479–495.

33. Mashwama, N.X, Aigbavboa, O.C & Thwala, D.W. (2018) "Challenges of Reconstruction and Development (RDP) Houses in South Africa, Proceedings of the International Conference on Conference on Industrial Engineering and Operations Management Washington DC USA September 27-29, pp 1695-1702, 2018.

34. Mashwama, N.X, Makgobi G, & Aigbavboa, O.C (2019) "Theoretical Examination of Sustainability on Low Cost Affordable Housing and Corporate GovernanceProceedings of the International Conference on Industrial Engineering and Operations Management Bangkok, Thailand, March 5-7, 2019

35. McDonnell, M. J., & Hahs, A. K. (2013). The future of urban biodiversity research: Moving beyond the 'low-hanging fruit'. Urban Ecosystems, 16(3), 397–409.

36. Nadikattu, R.R (2016) The emerging role of artificial intelligence in modern society International Journal of Creative Research Thoughts (IJCRT) | Volume 4, Issue 4 | ISSN: 2320-2882

37. Panchal H, Awasthi A. (2017) Theoretical modeling and experimental analysis of solar still integrated with evacuated tubes. Heat Mass Transfer. 2017;53(6):1943–1955. DOI:10.1007/s00231-016-1953-8

38. Purdy, M. & Daugherty (2016). Why Artificial Intelligence is Future of Growth, Retrieved from https://www.accenture.com/lv-en/_acnmedia/PDF-33/Accenture-Why-AI-is-the-Future-of- Growth.pdf (assessed 20 September 2023).

39. Relief Web (2021) Global Environment for Cities - GEO for Cities: Towards Green and Just Cities. Available at: https://reliefweb.int/report/world/global-environment-cities-geo-cities-towards-green-and-just-cities (Accessed 14 August 2023).

40. Taha, A.; Wu, R.; Emeakaroha, A.; Krabicka, J. (2018) Reduction of electricity Costs in Medway NHS by inducing pro-environmental behaviour using persuasive technology. Future Cities Environ. 2018, 4, 1–10.

41. Tanguay, G. A., Rajaonson, J., Lefebvre, J. F., & Lanoie, P. (2010). Measuring the sustainability of cities: An analysis of the use of local indicators. Ecological Indicators, 10(2), 407–418.

42. Tu H, Zhu M, Duan B, Zhang L (2021) Recent progress in highstrength and robust regenerated cellulose materials. Adv Mater 33(28):2000682.

43. Ullah, Z.; Al-Turjman, F.; Mostarda, L.; Gagliardi, R. Applications of artificial intelligence and machine learning in smart cities. Comput. Commun. 2020, 154, 313–323.

44. Umar, M., & Uhl, W. (2016). Integrative review of decentralized and local water management concepts as part of smart cities (Iowasmart).

45. United Nation, Global Mobility report 2017, PDF.

46. United Nations Development Program UNDP (n.d.b), Sustainable Development Goals - Goal 11: Sustainable cities and communities, in the website: https://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-11-sustainable-cities-and-communities.htm, (Accessed 14 August 2023).

47. United Nations Development Program UNDP (n.d.b), The Future We Want Biodiversity and Ecosystems - Driving Sustainable Development Biodiversity and Ecosystems Global Framework 2012-2020, PDF, P (16)

48. United Nations Environmental Program (UNEP) (n.d.a) GOAL 11: Sustainable cities and communities. Available at: https://www.unep.org/explore-topics/sustainable-development-goals/why-do-sustainable-development-goals-matter/goal-11 (Accessed 14 August 2023).

49. United Nations Environmental Program (UNEP) (n.d.a) GOAL 11: Sustainable cities and communities. Available at: https://www.unep.org/explore-topics/sustainable-development-goals/why-do-sustainable-development-goals-matter/goal-11 (Accessed 14 August 2023).

50. United Nations Environmental Program UNEP (n.d.b) Cities and climate change. Available at: https://www.unep.org/explore-topics/resource-efficiency/what-we-do/cities/cities-and-climate-change (Accessed 14 August 2023).

51. United Nations Environmental Program UNEP (n.d.b) Cities and climate change. Available at: https://www.unep.org/explore-topics/resource-efficiency/what-we-do/cities/cities-and-climate-change (Accessed 14 August 2023).

52. United Nations, Arab Report for Sustainable Development 2020, PDF, p (150-194).

53. Witte, H.D. (2016). On the scarring effects of job insecurity (and how they can be explained). Scandinavian Journal of Work, Environment & Health, 42, 99-102.

54. World Economic Forum (2020): How can we make cities more sustainable? Available at: https://www.weforum.org/agenda/2020/09/cities-sustainability-innovation-global-goals/ (Accessed 14 August 2023).

55. Yigitcanlar, T.; Mehmood, R.; Corchado, J.M. (2021) Green Artificial Intelligence: Towards an Efficient, Sustainable and Equitable Technology for Smart Cities and Futures. Sustainability, 13, 8952

56. Zekić-Sušac M, Mitrović S, Has A. Machine learning based system for managing energy efficiency of public sector as an approach towards smart cities. Int J Inf Manage. 2020;102074. DOI:10.1016/j.ijinfomgt.2020. 102074.