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The role of artificial intelligence in the implementation of the UN Sustainable Development Goal 11: Fostering sustainable cities and communities

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ABSTRACT

Addressing the global urgency for improved sustainable cities and communities, as per the United Nations Sustainable Development Goal (SDG) 11, requires innovative and disruptive approaches, which also include applying artificial intelligence (AI). While AI holds significant potential to address complex socio-economic and environmental challenges in cities, a comprehensive analysis of its applications and implications, particularly in urban contexts, is required to address the research gap in understanding how AI can be effectively deployed to meet the challenges. This paper reports on a study that evaluates how AI may facilitate achieving SDG 11. This assessment includes an expert-driven literature review, drawing insights from authoritative sources. In addition, a set of case studies illustrate practical applications of AI to improve urban sustainability. The combination of these approaches led to findings that underscore the pivotal role of AI in optimizing energy use, streamlining waste management, enhancing traffic flow, and contributing to environmental sustainability. However, according to the findings, AI implementation needs oversight to ensure it is ethical, inclusive, and privacy-respecting as an effective tool to aid decision-making. By fostering collaboration among planners, policymakers, and AI experts, the full potential of AI may be unlocked to shape sustainable urban environments and realize SDG 11.

1. Introduction

As cities continue to grow and environmental disasters wreak havoc with greater intensity, new tools and solutions are urgently needed to improve the sustainability of cities and communities so they can efficiently manage resources, limit their environmental impacts, and improve citizens' well-being (Sharifi et al., 2024). Old ways of managing cities are challenged when 60 % of the global population resides in urban areas, and by 2050, 68 % of the world's 9.7 billion (roughly 6.6 billion) people will be in cities, mostly in low- and middle-income

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African and Asian countries (UN Department of Economic and Social Affairs, 2018). New tools such as those supported by artificial intelligence (AI) may help to address these colossal challenges in providing crucial services such as transportation, health care, and education to all residents (Acharya et al., 2021). Rapid urbanization associated with increasing resource consumption, higher pollution, and rising greenhouse gas emissions requires resource management tools (UN-Habitat, 2022).

Accordingly, the United Nations (UN) Sustainable Development Goals (SDG), adopted in 2015, were developed to provide a comprehensive framework and direction for addressing these issues, but without identifying how to do so. Adding to existing challenges, a confluence of unfavorable conditions and crises, e.g., the COVID-19 pandemic, the war in Ukraine, (Ben Hassen & El Bilali, 2022; Zhao et al., 2022), has severely hampered the pursuit of the SDGs so that there are significant doubts about reaching the goals as planned by 2030 (Leal Filho, Viera Trevisan, et al., 2023). AI may enable the required accelerated progress, so this study examines how AI may address SDG 11, sustainable cities, and communities (United Nations General Assembly, 2015).

AI offers many creative, disruptive, and potentially new approaches, including the ability to combine several digital technologies and apply them to sustainable development issues (Ghobakhloo, 2020; Saner et al., 2020). Indeed, the rapid growth of technology has given rise to AI, offering many effective tools with significant potential to expedite advancements towards the SDGs (Nasir et al., 2023; Teh & Rana, 2023; Vinuesa et al., 2020). With careful and ethical oversight, AI may contribute to a greener, more sustainable world, assisting in mitigating and adapting to climate change (Coeckelbergh, 2021).

AI encompasses a diverse range of technologies such as data analytics and predictive modelling, machine learning (ML), deep learning, robotics, and more, providing the capacity to analyse extensive quantities of data ("Big Data"), identify patterns, and generate intelligent decisions (Schintler & McNeely, 2022; Yigitcanlar et al., 2021). Consequently, these new software tools present considerable potential for effectively tackling the complex sustainability issues of growing urban regions, including resource management, transportation, energy efficiency, waste management, and social equity (Yigitcanlar & Cugurullo, 2020). By applying intelligent data-driven decision-making techniques while considering privacy and other ethical issues, AI may improve how cities and communities are planned, developed, and governed while optimizing resource allocation and enhancing the quality of life for all residents (Sirmacek et al., 2023). AI may support low-carbon systems by fostering the development of circular economies and smart cities that effectively use resources (International Energy Agency, 2017). Smart systems underpinned by AI may support low-carbon cities by connecting various linked technologies, such as electric driverless cars and smart appliances, to a grid powered by renewable energy (e.g., smart grids) (Fuso Nerini et al., 2019). As AI analyzes big data, it can help anticipate weather events and climate systems, improving power grid projections and energy management (Coeckelbergh, 2021).

In addition to overcoming knowledge asymmetries and human emotional bias, both of which impediments to finding solutions for environmental sustainability (Cullen-Knox et al., 2017), AI holds significant value. According to Nishant et al. (2020), this value lies not only in its ability to lower society's resource usage intensities but, more importantly, in how it supports and encourages environmental governance at a higher level. Addressing knowledge gaps and promoting elevated environmental governance underscores the multifaceted potential of AI in advancing sustainable practices.

Although AI presents significant opportunities, it also gives rise to crucial ethical, social, and environmental concerns, such as threats to privacy and data protection, algorithmic governance, lack of transparency, human-AI interaction, and high energy consumption (Coeckelbergh, 2020). For instance, the rising energy needs of data centres and communication networks, driven by increased demand for AI processing and data storage, add to the carbon footprint and environmental impact (Belkhir & Elmeligi, 2018; Nordgren, 2023). It is imperative to consider these implications to ensure the responsible and inclusive implementation of AI technologies in urban environments. There are various pros and cons associated with AI, as summarized below.

- AI holds immense potential in advancing sustainability, characterized by its wide use, rapid development, and capacity to support decision-making. The broader integration of AI across various sectors can amplify its positive impact on sustainable practices. The rapid development of AI technologies ensures ongoing innovation, fostering continual improvements in addressing complex environmental and socio-economic challenges (Aina et al., 2023; Alshuwaikhat et al., 2022; Yigitcanlar et al., 2021).
- AI can streamline procedures, enhancing efficiency and resource optimization. Through data analysis and predictive capabilities, AI facilitates informed decision-making, contributing to more effective and sustainable solutions in energy consumption, waste management, and urban planning (Schintler & McNeely, 2022; Yigitcanlar et al., 2021)., as well as in education Lin and Yu (2023).
- However, the use of AI in sustainability also comes with certain limitations. Access to Information Technology (IT) is a prerequisite for leveraging AI benefits, potentially excluding communities with limited technological resources. Security concerns, including data privacy and protection, pose challenges that need careful consideration to ensure the responsible and ethical deployment of AI in sustainable initiatives (Aina et al., 2023; Sharifi et al., 2024).
- The wide-ranging social implications of AI implementation must be acknowledged. While AI has the potential to benefit society as a whole, there is a risk of exacerbating existing inequalities. Certain groups may face disadvantages regarding access to AI-driven solutions, creating a potential digital divide (Caragliu & Del Bo, 2023; Schintler & McNeely, 2022; Sharifi et al., 2024).
- A balanced approach is crucial in navigating the integration of AI for sustainability. Addressing limitations by ensuring equitable access, prioritizing security measures, and considering broader social implications will be essential to harness the full potential of AI as a powerful tool for advancing sustainability.

Moreover, evaluating AI tools is crucial in ensuring their effectiveness, safety, and ethical deployment. In particular, evaluation helps determine the performance of AI tools in terms of accuracy, speed, scalability, and resource efficiency. This involves benchmarking against existing methods or standards to assess whether the AI tool meets the desired objectives. Also, evaluation ensures that AI tools produce reliable and consistent results across different datasets and environments. It involves testing the robustness of AI models against various inputs, including edge cases and adversarial examples, to identify potential weaknesses or biases. Finally, evaluation may help to uncover ethical issues such as bias, fairness, transparency, and accountability in AI systems. Ethical evaluation involves assessing whether the AI tool respects privacy, human rights, and societal values and complies with relevant regulations and standards.

Accordingly, this paper aims to explore the role of AI in fostering sustainable cities and communities (SDG 11) by advancing the principles of sustainability and social progress outlined in the SDGs. The research gap addressed in this paper revolves around the need for a comprehensive analysis and synthesis of the diverse applications and implications of AI technologies, particularly within urban contexts. Despite the acknowledged potential of AI in advancing SDGs and sustainability, there is a gap in understanding how AI can effectively contribute to the multifaceted issues faced by cities. The text emphasizes the urgency of addressing this research gap, especially in the context of unfavorable conditions and crises, such as the COVID-19 pandemic and geopolitical events, posing significant obstacles to the timely achievement of SDGs. The outlined research objectives emphasize the paper's commitment to filling this research gap.

This research has three main objectives. Firstly, through an expert-driven literature review, the article aims to thoroughly examine the various AI applications, implications, and opportunities to improve the sustainability of cities and communities. Specifically, this study examines how AI-powered systems analyse data, optimize resource management, improve urban planning, enhance transportation systems, and enable smarter infrastructure. Secondly, the ethical, social, and environmental issues and obstacles related to integrating AI into sustainable cities and communities are examined. It highlights the need for responsible AI development, ensuring that AI systems are consistent with sustainability goals and societal progress. Thirdly, significant insights and recommendations are developed for policymakers, practitioners, and scholars working in sustainable urban development by presenting successful case studies, assessing consequences, and identifying research gaps and future research opportunities.

The following section explores the connection between AI and SDG 11. Section 3 details the methodological approach used in this study; Section 4 presents the case studies, results, and discussion; and finally, the main lessons from the paper are summarized in Section 5.

2. AI and SDG 11: sustainable cities and communities

The integration of AI in urban planning and management is fundamental for achieving the UN SDG 11, which aims to make cities and human settlements inclusive, safe, resilient, and sustainable. This literature review explores the synergy between AI and urban sustainability, focusing on the development of smart, sustainable cities and the application of AI in advancing sustainable urban environments (Beck et al., 2023). The section is divided into four main sub-sections: Defining AI, Conceptualising AI Urbanism, Urban sustainability, and the Role of AI in Urban and Sustainable Development.

2.1. Defining AI

AI includes many systems, including robotics and information systems, that simulate and support human intelligence and activities, including recognition, comprehension, learning, and intelligent actions (Wirtz et al., 2019). AI offers many potential existing and future applications for sustainable, resilient cities (Schintler & McNeely, 2022). An example of a broad AI category is the "Artificial Intelligence of Things" (AIoT), which refers to commonplace Internet-connected devices known to other devices through their connectivity, sharing information across databases (Marr, 2017). This connectedness transforms the material and natural worlds, interwoven into an information system facilitated by AI. In cities, AIoT enhances energy and resource efficiency, transportation systems, waste management, and environmental conservation (Bibri et al., 2024).

2.2. Conceptualising AI in urbanism

The emergence of AI is gaining ground and becoming an integral part of today's functional societies (Sharifi et al., 2024). A critical context of its operationalization is in urban spaces and processes, such as construction, traffic management, and manufacturing. Palmini and Cugurullo (2023) maintain that in Western modernity, there is an increasing shift in the quality of the connection between society and technology. Early conceptualization of this relationship between society and technology was captured by Francis Bacon (1561–1626) (Winner, 1978) in his social utopia termed the New Atlantis, which underscores technology as a powerful force that drives societal improvement (Cugurullo, 2021). This idea of technologically powered societies has since gained momentous recognition, touching on different sectors and disciplines in science, social science, arts, and humanities (Cugurullo et al., 2023; Palmini & Cugurullo, 2023). This is so even as many cities are being developed as smart cities (Clement et al., 2023), with AI taking a central stage in urban life. Given the two words that make up AI, that is, "artificial" and "intelligence" Cugurullo defined urban AI as "artifacts operating in cities, which are capable of acquiring and making sense of information on the surrounding urban environment, eventually using the acquired knowledge to act rationally according to pre-defined goals, in complex urban situations when some information might be missing or incomplete" (Cugurullo, 2020:3). What this definition implies is that the reliance on AI urbanism expressed in different forms such as autonomous vehicles, urban robots, city brains or urban software agents are not linear and require multifaceted inputs from other smart technologies, including sensors (Cugurullo et al., 2023). In this light, there is a close relationship between smart urbanism and AI urbanism, with the latter posing emerging opportunities and challenges that touch on sustainability.

2.3. Urban sustainability

Urban sustainability and sustainable urban development represent critical facets of contemporary urban planning and policymaking, aimed at addressing the multifaceted challenges of rapid urbanization and its impact on environmental, economic, and social systems (Kolesnichenko et al., 2021). These concepts emphasize the importance of developing cities in a manner that ensures a balance between growth and the preservation of natural resources, promotes equitable social inclusion, and fosters economic viability, thereby enhancing the quality of life for all residents without compromising the ability of future generations to meet their own needs. Sharifi et al. (2024) conducted a systematic literature review on smart cities and their alignment with SDGs, identifying both co-benefits and trade-offs associated with smart city initiatives in the context of sustainable development.

SDG 11, adopted by the United Nations in 2015 as part of the 2030 Agenda for Sustainable Development, explicitly targets making cities and human settlements inclusive, safe, resilient, and sustainable. It encompasses a broad range of objectives, including ensuring access for all to adequate, safe, and affordable housing and basic services; providing safe, affordable, accessible, and sustainable transport systems; enhancing inclusive and sustainable urbanization; protecting the world's cultural and natural heritage; reducing the adverse effects of natural disasters; reducing the environmental impact of cities; and providing access to safe, inclusive, and accessible green and public spaces (United Nations General Assembly, 2015). The development of smart cities, or smart sustainable cities, represents a pivotal advancement towards achieving urban sustainability (Dionisio et al., 2023). Smart sustainable cities integrate information and communication technologies (ICT) and other means to improve the efficiency of urban operations, services, and connectivity while ensuring that such advancements contribute to the SDGs (Clement et al., 2023). These cities leverage big data, the Internet of Things (IoT), AI, and other technological innovations to optimize resource use, reduce emissions, improve transportation systems, and enhance the overall quality of urban life. The integration of these technologies into urban planning and management processes facilitates more informed decision-making, improves service delivery, and fosters greater engagement between citizens and their governments (Bibri & Krogstie, 2020; Yigitcanlar et al., 2021). This literature collectively underscores the significance of leveraging responsible AI to navigate the complexities of urban development, suggesting that a strategic deployment of AI could significantly contribute to creating more sustainable, efficient, and liveable urban environments in line with SDG 11 objectives.

Urban planning is currently capitalizing on AI-driven insights to strike a balance between essential urban components, from public utilities and green spaces to efficient traffic flows. These optimized city layouts, informed by real-time data and parallel the concepts, were put forth by Bettencourt and West (2010) in their seminal work on the science of cities. The transformative impact of AI extends beyond urban design and redefines urban mobility. In progressive cities such as San

Francisco, AI-based projects have significantly reduced traffic congestion, enhancing public transportation routes. In terms of pollution challenges, applications such as those utilized in Beijing pinpoint pollution sources with unprecedented accuracy, enabling timely and effective interventions (Buonomano et al., 2023). In the energy sector, another pivotal urban consideration, European cities are adopting AI-powered smart grids. These systems dynamically optimize energy distribution, ensuring efficient consumption and minimizing waste. AI tools are carving out their niche in architecture and construction, fostering energy-efficient building designs, a trend increasingly recognized in global architectural discourse. These advances underline AI's vast potential in achieving SDG 11 and indicate a future where urban environments are increasingly sustainable, efficient, and aligned with global sustainability benchmarks (Singh et al., 2023).

Moreover, the rise of participatory urban planning, facilitated by digital platforms and AI, fosters inclusivity by allowing residents to engage in decision-making processes. As highlighted by Alizadeh and Hitchmough (2019), such approaches empower marginalized communities and ensure that urban development initiatives address their unique needs and concerns. Consequently, AI contributes to the technical optimization of cities and serves as a conduit for democratic urban transformation. As AI continues to penetrate urban development, it introduces novel opportunities for monitoring and evaluating progress towards SDG 11 targets. Real-time data streams, harnessed through IoT devices and sensors, offer unprecedented insights into urban dynamics. This data-driven approach aids decision-makers in identifying emerging trends, responding to crises promptly, and fine-tuning policies for maximum impact. For instance, AI-powered predictive models can anticipate spikes in energy demand or congestion, enabling proactive interventions that minimize strain on resources and enhance urban resilience. Additionally, AI's analytical capabilities can streamline the measurement of indicators related to SDG 11, facilitating more accurate assessments of progress. By automating data collection and analysis, AI mitigates the challenges posed by data accessibility and standardization (Alshuwaikhat et al., 2022; Klopp & Petretta, 2017). Nonetheless, ethical considerations, such as data privacy and algorithmic bias, must remain paramount in integrating AI-driven solutions within urban governance frameworks, ensuring that technological advancements remain aligned with the overarching principles of sustainability and inclusivity. In this regard, collaboration between technology experts and urban practitioners is vital to co-create solutions that address local challenges and leverage AI's transformative power. Furthermore, as AI becomes increasingly ingrained in urban systems, fostering a culture of transparency, accountability, and open dialogue is imperative. This approach will engender trust among citizens, enabling them to actively participate in shaping AI-driven urban transformations and ensuring that the benefits of technological progress are equitably distributed across diverse populations. In essence, the fusion of AI's potential with human agency holds the key to steering urban development towards a sustainable and inclusive future. Therefore, in order to efficiently monitor the advancements of SDG 11 indicators, future studies on urban metabolism should actively involve collaborative co-design with local communities. This approach ensures the delivery of pertinent empirical evaluations coupled with practical indicators along the specific context (Musango et al., 2020).

In this sense, the convergence of AI and urban policy holds immense promise in reshaping the urban landscape. As AI technologies continue to advance, they offer a unique opportunity to create smarter, more responsive cities. The future of urbanization, shaped by the synergy of human innovation and technological advancement, has the potential to redefine cities and how we perceive and interact with urban environments.

2.4. The role of AI in urban and sustainable development

The advancement of computational capabilities and technologies, such as AI, opens new pathways for addressing urban sustainability and development issues (Yigitcanlar et al., 2021). In recent years, AI has significantly progressed and is now instrumental in remote sensing and geospatial analysis. AI algorithms and deep learning frameworks have proven effective in monitoring land cover changes and analyzing urban and natural expansion patterns (Al-dousari et al., 2023; Mishra & Singh, 2023). Furthermore, AI's capabilities in climate and weather pattern monitoring are notable contributions to environmental sustainability and urban planning (Malla & Arya, 2023; Mishra & Arya, 2020), enhancing our response to climate variability and extreme weather events, which are vital for sustainable urban development.

The AI has applications in several applications in Urban Planning and Design, namely:

- **Disaster Preparedness and Resilience:** AI's predictive capabilities improve early warning systems and disaster response strategies, increasing city resilience to natural disasters.
- **Waste Management:** By optimizing collection routes and recycling processes, AI-powered systems contribute to sustainable waste management.
- **Water Management:** AI algorithms enhance water demand forecasting, leak detection, and distribution system optimization.
- **Public Services and Governance:** Enhanced data analysis and smart governance systems facilitated by AI improve public administration, service delivery, and citizen engagement.
- **Affordable Housing:** AI analytics help identify optimal locations for affordable housing, considering accessibility, infrastructure, and community needs.
- **Healthcare Services:** AI's role in healthcare through predictive analytics and remote monitoring leads to better public health outcomes.
- **Preserving Cultural Heritage:** Technologies like image recognition and virtual reality, powered by AI, aid in conserving cultural heritage.
- **Transportation Planning and Smart Mobility:** AI-driven solutions in transportation planning enhance traffic flow, reduce congestion, and promote sustainable and accessible transportation networks. Intelligent traffic management systems and predictive maintenance are key to this evolution towards smarter mobility solutions.
- **Smart Energy Systems:** In the realm of energy management, AI is pivotal in optimizing energy consumption in buildings and through smart grids, promoting sustainable energy practices and reducing overall consumption.

Urban sustainability involves developing and implementing strategies and practices that seek to meet the needs of the present without compromising the ability of future generations to meet their own needs within urban settings. This concept is closely tied to the development of smart, sustainable cities, which leverage technology and innovation to improve efficiency, reduce environmental impact, and enhance the quality of life for their inhabitants. SDG 11 targets the challenges of rapid urbanization, aiming to promote sustainable urban development by improving access to essential services, reducing pollution, enhancing urban resilience, and promoting community inclusivity.

3. Methods

The importance of AI to the success of SDG 11, that is, sustainable cities and communities (Department of Economic and Social Affairs, n.d.), was assessed through an expert-driven literature review, delving into authoritative sources. This foundational phase aimed to establish a robust understanding of the theoretical framework and existing knowledge surrounding AI's role in achieving urban sustainability. The rationale behind the paper is the perceived need to evaluate how AI may facilitate achieving SDG 11.

Building upon this groundwork, a series of case studies are next meticulously examined, providing real-world illustrations of how AI technologies have been practically implemented to contribute to sustainability in various urban contexts. These case studies serve as valuable examples, offering insights into the diverse applications of AI in areas such as urban planning, transportation, energy management, disaster preparedness, waste management, water conservation, public services, housing projects, healthcare, and cultural heritage preservation. The case studies were chosen based on their significance within a city's context. A total of 4 items were selected as examples of using AI to implement the different aspects of SDG 11. Yin's (2017) methodological approach was applied in determining and analyzing the cases to complement the information available in the literature review. The analysis highlights the implications of using AI in several urban settings. Altogether, the four sets of case studies allowed the authors to deepen the discussion on AI's role in contributing to the success of the SDGs, and SDG 11 in particular.

The literature search and case studies laid the foundation for a comprehensive analysis and discussion. This phase involved synthesizing the findings from the literature review and case studies identifying patterns, trends, and critical insights. The goal was to provide a nuanced understanding of the multifaceted ways AI intersects with SDG 11, fostering sustainable cities and communities. This comprehensive analysis not only highlighted the potential of AI but also addressed challenges, ethical considerations, and the need for inclusive, privacy-respecting implementations.

Fig. 1 details the methodological approach used in this study.

The case studies provide a deeper insight into how AI is being used to implement SDG 11. By examining the common themes and results across these studies, it is possible to understand the evolution of AI technologies in cities and communities globally. The description of the study cases was divided into four categories: AI and Transport Planning, AI in Traffic Management, AI in Smart Energy Systems, and AI in Urban Planning. These categories were based on SDG 11 targets, described in Table 1. Insights garnered from the literature and case studies provide an assessment of potential AI applications to support the implementation of SDG 11. This study examined how AI-powered systems can analyse data, optimize resource management, improve urban planning,

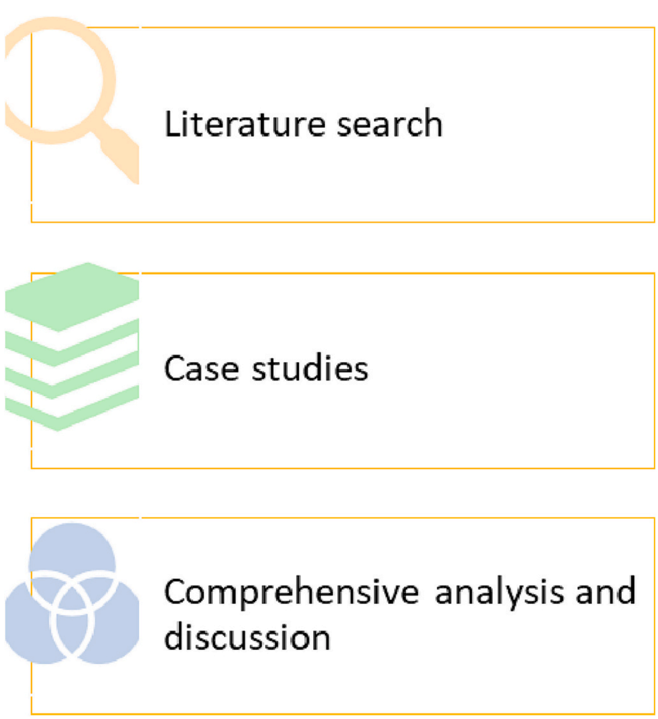

Fig. 1. Phases in the research.

Table 1
SDG targets used for categorizing the addressed case studies.

Target 11.2	By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport.
Target 11.6	By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management.
Target 11. b	By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015–2030, holistic disaster risk management at all levels,
Target 11. c	Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials.

Source: based on United Nations SDG 11 targets (United Nations General Assembly, 2015).

enhance transportation systems, and enable smarter infrastructure. The outcomes of the analysis are presented in the next section.

4. Results and discussion

The study has identified a set of possibilities in terms of how AI can be utilized to enhance urban planning processes. The following section is divided as follows. The first subsection provides an overview of AI potential processes and possibilities. The second subsection contains case studies divided into five subsections: case studies on AI in general urban planning, case studies on AI in transport planning in cities, case studies on AI in traffic management, and case studies on AI in smart energy systems.

4.1. Overview of AI potential processes and possibilities

In this section, a comprehensive exploration of diverse applications unfolds, highlighting the transformative capabilities of AI. The first subsection, 4.1.1 Data Analysis, delves into the pivotal role AI plays in extracting meaningful insights from vast datasets, revolutionizing decision-making across industries. Subsection 4.1.2, Predictive Analytics, demonstrates AI's prowess in forecasting future trends and outcomes, offering invaluable foresight for strategic planning. Subsection 4.1.3, Simulation, Modelling, and Urban Management, underscores AI's impact on urban planning through advanced simulation and modelling techniques. In 4.1.4 that is on Traffic Management, the focus shifts to AI-powered solutions optimizing traffic flow and mitigating congestion, while 4.1.5 on Energy Efficiency explores AI applications in enhancing energy management systems for sustainable and resource-efficient practices. Finally, Subsection 4.1.6 discusses the use of AI for smart infrastructure planning. Together, the different subsections extensively paint a vivid picture of AI's multifaceted potential, driving innovation across data analysis, prediction, urban planning, traffic, and energy domains.

4.1.1. Data analysis

In terms of data analysis, AI can process vast amounts of data collected from various sources, such as sensors, satellites, and social media, to provide valuable insights for urban planning. It can also analyse traffic patterns, energy consumption, and environmental factors to understand the dynamics of a city. AI applications are facilitated by data collection and analysis. AI systems can acquire data and learn from it even under uncertainty, ultimately making decisions without supervision (Cugurullo, 2020). AI, machine learning, and blockchain systems that enable various smart city systems are underpinned by massive amounts of data referred to as "big data". Much of that data comes from the IoT, including mobile applications and social media platforms, and the analysis is done "in the cloud" - cloud computing (Allam & Dhunny, 2019; Arfat et al., 2017; Yigitcanlar & Cugurullo, 2020). Some examples include Samsung's Brightics AI which accelerates particular AI systems development with pre-developed data analysis modules (Gupta & Degbelo, 2023; Samsung, 2023). Prometea is another example of data analysis AI applied within judicial systems, where it can even assist in making legal decisions (Gupta & Degbelo, 2023. Although city services are facilitated by AI, misinformation dissemination and personal information security risks are high, dealing with these privacy concerns is also within the realm of ICT solutions such as blockchain (Braun et al., 2018). Urbanites must pay attention to the integrity and transparency of their institutions overseen by strong democracies, or else elites who rise to power could use smart city systems to control citizens. Citizens must be savvy about their data security as it is collected, stored, and disseminated for analysis and use. Blockchain plays a role in urban data security because as it analyzes data, the data are kept in a decentralized repository in the cloud, referred to as a distributed ledger (Ahmed et al., 2022). Blockchain tracks devices and sensors as part of the IoT using smart contracts, which are automated transactions without central oversight. Because the ledger is shared and distributed, this increases trust as a more transparent system (Ahmed et al., 2022). This system is expected to be more eco-efficient and effective by reducing computing resources and power consumption while using clean energy. Blockchain has evolved over time, and version 4.0 has improved through increased privacy and security to enable its use in a broader set of industrial applications (Ahmed et al., 2022). The fifth version, which is still under development, will assist in integrating the various advanced digital technologies for improved interoperability and security, but storage will remain a challenge (Ahmed et al., 2022). Overall, at the basic level of data collection and security, several urban citizen-centric issues are relevant as we use data in AI and other related advanced IT systems (Degbelo et al., 2016; Gupta & Degbelo, 2023). Citizens must be engaged, improve their data literacy for their own protection, and be involved in co-developing the urban systems they will use. Therefore, citizens and their urban systems will gain from the combination of open, accessible, quantitative, and qualitative data to develop more holistic, inclusive, relevant, and user-friendly applications that can deliver personalized services and work towards making cities sustainable according to SDG 11 (Gupta & Degbelo, 2023).

4.1.2. Predictive analytics

AI algorithms can be used for predictive analytics by leveraging historical data to predict future trends and patterns in urban development. This information can help urban planners make informed decisions about the demographic patterns and well-being of the populace, infrastructure investments, land use, and transportation systems. With a projected global population of 9.7 billion people by 2050 due to increased life expectancy while fertility falls, along with the increasing migration into cities (United Nations Department of Economic and Social Affairs, Population Division, 2022), developing holistic solutions to deal with several urban sustainability issues that consider diverse and changing demographics becomes more complex. Sophisticated information technology support systems applying "big data" and predictive analytics can help reduce complexity (Batty, 2018). AI systems used appropriately with knowledgeable and ethical human oversight can offer some potentially helpful tools (de Lange, 2020). For example, while many cities experience inward migration and must provide services for youth as they mature, populations across Western nations are also aging (United Nations Department of Economic and Social Affairs, Population Division, 2022). By 2050, over 1.5 billion people could fall into the 65 years or over category, matching the number of children under age 12 (United Nations Department of Economic and Social Affairs, Population Division, 2022). Policymakers and institutional designers can turn to AI to integrate specialized health and wellness, social, safety, supply, transportation, exercise, and leisure services with specialized housing for growing numbers of older adults (Skouby et al., 2014).

This may include the use of robots, monitoring, and home-based rehabilitation systems in smart homes connected to smart cities (known as Integrated Smart Home and Smart City system (ISHSC)) to enable extended independent living that reduces social isolation (Skouby et al., 2014). Older adults also need increased social security and pension support systems that will draw upon limited financial resources as populations grow and inequality increases (United Nations Department of Economic and Social Affairs, Population Division, 2022). Issues for older adults during the COVID-19 pandemic were heightened in problematic long-term care home settings where social interaction and outdoor time became limited. This recent experience shed light on the problems we will face in the future if we do not start designing now for this demographic. The literature explains that AI can help us devise ways to improve the quality of life while reducing healthcare costs, personalizing services, predicting future needs, and making them more effective for older people (Skouby et al., 2014). However, increasing numbers of youth also need services. Quality health care and education are critical if countries are to benefit from the "demographic dividend", an opportunity for accelerated economic growth through more significant numbers of working-age adults (Aged 25–65 years) (United Nations Department of Economic and Social Affairs, Population Division, 2022). While attempting to educate many youth, the standard of education is falling due to a lack of resources (United Nations Department of Economic and Social Affairs, Population Division, 2022). Instead, the world, especially in growing urban centres in Asia, needs new skills and more sophisticated education to deal with the upcoming complex challenges (Batty, 2021; United Nations Department of Economic and Social Affairs, Population Division, 2022). Under constrained resource circumstances, AI may facilitate this education goal but also create problems for youth facing underemployment due to automation (Batty, 2018; de Lange, 2020). They must choose careers dealing with unexpected events and non-routine behavior (Batty, 2018).

4.1.3. Simulation, modelling and urban management

As to simulation, modelling, and urban management, AI-powered simulations can create virtual environments to test and visualize urban planning scenarios. Planners can simulate the effects of different interventions, such as the construction of new buildings or changes in zoning regulations, to understand their impact on the urban landscape. Urban design, planning, and resource optimization management are urban governance responsibilities assisted by advanced IT systems, including AI (Voto, 2017). Planning, saving, and reducing the use of resources in the urban context can result in many positive feedback effects and externalities. For example, improved energy conservation, efficiency, and the use of clean energy can lessen local pollution and GHG emissions for enhanced human health and reduced climate impacts so that cities offer a higher quality of life and experience higher productivity, thereby improving economic output, among many other benefits (Geller et al., 2004; Wen et al., 2022). Because urban activities are increasing in number and complexity, they require a considerable number of resource management transactions; thus, blockchain can be assistive to resource management types of AI integrated into urban planning (Allam & Dhunny, 2019; PwC, 2016). A secure digital ledger can manage these smart contract transactions automatically in a single set of records (Allam & Dhunny, 2019; Reyna et al., 2018). This transparent and accessible system can enable citizen engagement in governance, thereby designing a city with consideration for local preferences and inclusive of critical local design parameters. For example, a smart city dashboard enables experimental inputs to develop scenario analyses that citizens can visualize (Contreras-Figueroa et al., 2021; Marsal-Llacuna, 2020; Monteiro et al., 2018). Trust and accuracy are improved by blockchain technology, which reduces the risk of data manipulation and increases the likelihood of local acceptance of the designs (Huang et al., 2021). Other AI-related advancements that assist in urban planning and resource management involve Earth Observation (EO) technologies

(Gupta & Degbelo, 2023). For example, mapping slums and tracking the progress of locally informed policy helps cities address socioeconomic inequality and related infrastructure problems, such as clean water delivery to inhabitants (Owusu et al., 2021). These systems include machine and deep learning. Alongside this aim of addressing urban inequality, earth observation datasets enable the application of Artificial Neural Network-Multilayer Perceptron and Markov Chain (MLP-Markov) and Cellular Automata and Markov Chain (CA-Markov) to model urban growth (Mustak et al., 2022).

Moreover, land use and land cover changes are detected using these EO datasets and AI, such as deep learning neural networks (Helber et al., 2019). Other examples of resource management functions that AI facilitates include energy management, waste management, and pollution monitoring, as demonstrated by NOAA Air Resources Laboratory (ARL), for example (Bedi et al., 2022; Gupta & Degbelo, 2023; NOAA, 2021). The construction sector can also be greener by combining advanced technologies (Allam & Dhunny, 2019). Construction planning systems integrate green spaces, walls, and roofs into building plans, including the building's power, water, and waste management systems (Yezioro et al., 2008). The positive outcomes of these planning and construction systems are many. They include more efficient and better land use that considers requirements for agriculture, increased compactness to improve the economics of mass transit systems, reduced congestion and emissions, and walkable, community-friendly cities (Gaigné et al., 2012; Zhang, 2017).

4.1.4. Traffic management

AI can support traffic management by analyzing real-time data from traffic sensors, GPS, and social media to identify congestion hotspots and suggest alternative routes. It can also optimize traffic signal timings based on current conditions to alleviate traffic congestion. Transportation is the backbone of a city's infrastructure, an ongoing focal investment that demands special attention (Dai et al., 2018). However, as these investments transform into Intelligent Transportation Systems (ITS), including Vehicular Ad hoc Networks (VANETs) and Mobile Ad hoc Networks (MANETs), advanced information technologies become a focus of this backbone (Fatemidokht et al., 2021; Mohanty et al., 2016). ITS is addressing many urban issues stemming from transportation. Climate change is aggravated to a great degree by emissions from fossil fuel use in urban transportation, while local air pollution from the same transportation harms human health; but technology offers alternatives, and clean innovations are further beneficial by increasing city wealth (Creutzig et al., 2019; de Lange, 2021). Equitable access to city services, activities, and employment is threatened by poor urban transportation infrastructure, but this, too, can be addressed with the help of AI and complementary advanced technologies (Foth et al., 2013; Sharifi et al., 2024; Soberman, 1997). Moreover, car traffic congestion on multi-lane highways increases commute times and frustration while paving over green agricultural lands and threatening economic productivity, water, and food security; but we have technological solutions, some of which may reduce the existing issues and some that may address root causes (Joubari et al., 2022; Khozema, 2023; Liu et al., 2021; Mądziel et al., 2021). These are just a few of the many consequences of problematic transportation planning and implementation that can begin to be resolved with the assistance of AI. In some cases, the mistakes were avoidable, such as paving over green space, and AI could have offered alternative solutions for the public and politicians to consider. After the poor decisions have been made, some AI solutions may help reduce the ongoing damage. Cities need wide-ranging transportation solutions immediately. But even when obvious solutions are enabled by available transportation technologies and the private business expertise needed to implement them, they are often delayed by political holdups and incompetent city management (Cook, 2023; de Lange, 2023; Larson & Rao, 1984). AI and other advanced IT have been and continue to be instrumental in the development of many of the technological transit solutions, such as autonomous electric vehicles (EVs), high-speed electric commuter rail, car sharing, and drones (otherwise called unmanned aerial vehicles (UAVs)) (Allam & Dhunny, 2019; Parveen et al., 2022; Ullah et al., 2020). However, AI can also facilitate the political and problematic management stalemates to solve problems and assist in making complex decisions that arise in multi-modal transportation systems (Parveen et al., 2022; Quan et al., 2019). AI can make cities smarter and cleaner by supporting transport planning information systems, illustrated by the dashboards above with scenario analyses, that design in passive sustainability through the addition of safe bicycle lanes and pedestrian-friendly areas alongside roads and mass transportation (Allam & Dhunny, 2019; Huang et al., 2021).

Multi-modal transport solutions are complicated, and AI systems can work out design solutions with multiple constraints. When well-designed, multi-modal transport is more equitable, accessible, and environmentally benign. Citizens have more, faster, and more comfortable travel choices depending on individual preferences, thus increasing the quality of life and improving the economy (Parveen et al., 2022). Some recent research adds that AI is used in the ongoing logistics and management of public multi-modal transportation, including applications for predictive maintenance, scheduling, and timetabling with multi-modal trip planning, ticketing, customer analytics, and real-time operations management (Parveen et al., 2022). The complexity of multi-modal transport creates voluminous data that needs AI to analyse and manage it. Technology solutions such as EVs and the awaited autonomous EVs can aid in reducing fossil fuel emissions and congestion where roads are already ubiquitous. Electric vehicles reduce overall emissions and integrate smart AI systems such as predictive GPS information and self-driving capabilities to optimize road conditions (Gupta & Degbelo, 2023; Yigitcanlar & Cugurullo, 2020). Also, when car-as-a-service is utilized (and in the future, autonomous EVs), commonly known as car sharing, it can result in a reduction of cars on the road. If the car service is sufficiently reliable, then buying a car can be avoided, even in areas where there is no public transit service. Another technology that can reduce vehicles, emissions, and congestion is high-speed electric rail (HSR) for local or long-distance commuting. AI facilitates HSR, ubiquitous in Europe and densely populated areas of Asia such as China, for example (Yin et al., 2020). AI supports design, planning, control, and maintenance. In European systems, AI is used in fault diagnoses in train control systems (Zang et al., 2019). Microwave sensors have been tested in simulations to detect cracks in rails to prevent fatal accidents remotely (Vijayakumar et al., 2009). China uses AI in the intelligent construction of railway engineering (ICRE) and support systems such as building modelling, life cycle management, maintenance, and communications systems, among others (Lu et al., 2019).

The applications for AI in HSR are growing and seem limitless. Delivery approaches are also changing with new AI-supported technologies. Delivery trucks, also becoming electrified, consolidate package deliveries. Deliveries have become more popular since the COVID-19 pandemic. Thus, the delivery cost has also fallen with increasing volumes, adding to the convenience and time savings of online purchasing from home. Delivery trucks reduce the number of individuals driving to purchase goods, which is even better for lowering emissions if they are hybrid or electric trucks. However, delivery will be further improved by electrified, AI-supported UAVs (drones) flying to deliver packages, thereby not using congested roads (Ullah et al., 2020).

Advanced technologies can also be combined to solve other transportation challenges. The initial analysis is important for understanding the challenges. For example, as traffic congestion remains a challenge when not reduced by removing cars from the roads, an ITS uses advanced sensors to generate big data to apply AI and deep learning to understand traffic flows and predict congestion (Ullah et al., 2020). AI can also support autonomous traffic control using vehicle-to-anything (V2X) communication through a distributed vehicle and infrastructure network to exchange real-time traffic information (Joubari et al., 2022). AI systems will also prevent attacks through communication and GPS systems where, for example, drones communicate with autonomous vehicles or navigate package delivery (Fatemidokht et al., 2021; Ullah et al., 2020). Overall, these technology solutions - car-as-a-service, high speed rail, and cleaner delivery systems - increase equitable access to goods and services, activities, and employment. As volumes increase, these shared transportation services can grow their reach and availability while prices decline. As the success of these approaches grows, the services can invest to become more specialized to various circumstances, pressured by market competition. As car ownership is relinquished and/or cars are left at home, congestion, frustration, and the political imperative to add more roads is eliminated. This technology pathway to emissions reduction is more convenient, equitable, accessible, efficient, and cost reducing (Ahmed et al., 2022). Moreover, when we reduce pollution and reduce the damage/use of ecosystems for transport purposes, we gain through improved water, food, and energy security while reducing health care costs.

4.1.5. *Energy efficiency*

AI algorithms can optimize energy efficiency usage in urban areas by analyzing data from smart grids, buildings, and infrastructure. It can identify areas of high energy consumption, recommend energy-saving measures, and help design sustainable urban environments. Energy infrastructure is being built using technology to increase privacy and stop cyber-attacks while giving power users more control over their usage of power (Ahmed et al., 2022). When users have input, they can make choices to conserve energy, thereby reducing energy waste so that clean energy systems are more efficiently utilized and backup fossil fuels are used less (Ahmed et al., 2022). Smart energy infrastructure, enabled by AI predictive analytics, can deliver lower cost, reliable, and cleaner power consumption that can also protect against disaster, increasing with climate change, by adding forecasting, early warning, and financial systems (Yigitcanlar & Cugurullo, 2020). Environmental monitoring and more environmentally protective energy systems using AI, such as for detecting and capturing pollution, can help address climate change, pollution, and biodiversity loss (Yigitcanlar & Cugurullo, 2020). AI helps by creating accurate energy maps using big data, with some of it collected from smart grids, for energy planning and integrating renewable energy, thus accelerating the replacement of fossil fuels (Allam & Dhunny, 2019; Ullah et al., 2020). AI is also applied within home energy systems, creating smart homes that offer convenience using domestic robotics ("domotics") while using energy more economically (Murphy, 2018).

4.1.6. *Smart infrastructure planning*

AI can help to optimize (smart) infrastructure planning by considering multiple variables, such as population density, traffic flow, and environmental impacts of urban projects. It can also assist in designing efficient transportation networks, optimizing utility services, and identifying suitable locations for suitable public projects (e.g., new roads) or public amenities like parks and schools. Aside from transportation, AI and other advanced information technologies can enhance many aspects of a city's infrastructure (Gupta & Degbelo, 2023). The potential applications are almost endless, so a few are outlined here. First, a priority for considering how AI is implemented should always be the human rights of citizens, which often translates into a focus on privacy and data security (de Lange, 2020). These considerations should represent the primary boundaries for considering how AI is implemented to improve infrastructure. The following discussion covers the topics: how AI assists in the oversight of infrastructure, service infrastructure and security, energy management, water and waste management, and buildings and construction. The term infrastructure can refer to many supporting features within a city. Still, no matter which infrastructure it is, it is better maintained, safe, and operational when ongoing oversight exists. Across several cities in Malaysia and China they have capitalized on AI by developing "city brains" to manage the energy, safety, and transportation systems (Yigitcanlar & Cugurullo, 2020). These systems are tremendous in some ways. For example, they can oversee traffic to predict traffic flow and notify police of car accidents (Macrorie et al., 2021). However, these systems also violate privacy to the extent that they could be considered surveillance that enables state control by an authoritarian regime (Macrorie et al., 2021). This illustrates the earlier statement about ethical boundaries that are so important for maintaining human rights while managing growing cities that need sustainable solutions. Most of these oversight systems rely on information, but how to draw the line on what information is collected and who has access to it is not always easy to discern, especially when many non-experts in data security and privacy are involved in design. Designers of city oversight systems will come from a variety of disciplines, and when the public is also involved in design, where possible, it may be difficult to overcome disagreement. The literature offers discussions on principles for striking this balance between innovation and protecting the public (Hemphill, 2020). An approach to mitigating security and privacy problems is to use the precautionary principle, thereby prioritizing human rights over technical solutions when there are doubts about public protection (de Lange, 2020; Hemphill, 2020). The governmental imperative to improve services and the security of city services infrastructure is related to oversight. Automation through AI is becoming ubiquitous across city services and improving citizens' overall quality of life, especially as more personalized services are being demanded (Mishra & Chakraborty, 2020; Mishra & Tyagi, 2022). However, as the IoT increases connectivity and data is more openly available, cyber security becomes more of a concern due to the increased accessibility through systems and device connections. Embedded in these automated unsupervised systems is also improved security to increase citizen safety (Yigitcanlar & Cugurullo, 2020). Drones and other AI systems help identify hackers, terrorism attempts, and organized crime like human and drug trafficking (Allam & Dhunny, 2019). For example, the banking industry relies heavily on advanced cyber security systems using AI to stop hacking into accounts (AL-Dosari et al., 2022). AI assists water and waste management by delivering clean water security. AI assists through various functions, including water sanitation, quality, and drought planning (Yigitcanlar & Cugurullo, 2020). However, these vital infrastructure services are not always fairly distributed across cities (Pandey et al., 2022). The imperative to address these inequalities rises as environmental issues further impinge on urban contexts, leaving large populations vulnerable (Parthasarathy, 2018). Technologies such as AI help cities to fix and expand infrastructure while considering these complexities that individual city managers would otherwise find overwhelming. Buildings and construction are increasingly applying AI tools with big, open data in more transparent and democratic city design decision-making (Allam & Dhunny, 2019; Barns, 2016). By accelerating the building of more housing using decision tools, unaffordable cities like Toronto and Vancouver in Canada may develop their housing stock more quickly about increasing populations driven by immigration. Moreover, AI tools such as digitizing sketch maps can help ensure that indigenous land rights are incorporated into city planning (Chipofya et al., 2020; Gupta & Degbelo, 2023).

4.2. *Case studies*

AI has revolutionized life globally and can contribute to sustainable development worldwide (Leal Filho, Eustachio, et al., 2023; Leal Filho, Yang, et al., 2023). SDG 11 progress since 2025 has not been optimal, and further effort is needed to enhance progress, namely in terms of investment, technology, and infrastructure (Leal Filho et al., 2022). The role of AI in contributing to the SDGs has been studied by Vinuesa et al. (2020), who documented its potential to enhance each SDG technological improvement, also in the case of SDG 11. In the scope of SDG 11, Fig. 2 and the case studies presented in Tables 2 to 5 showcase the contribution of AI to overall sustainable development in several areas, discussed in detail.

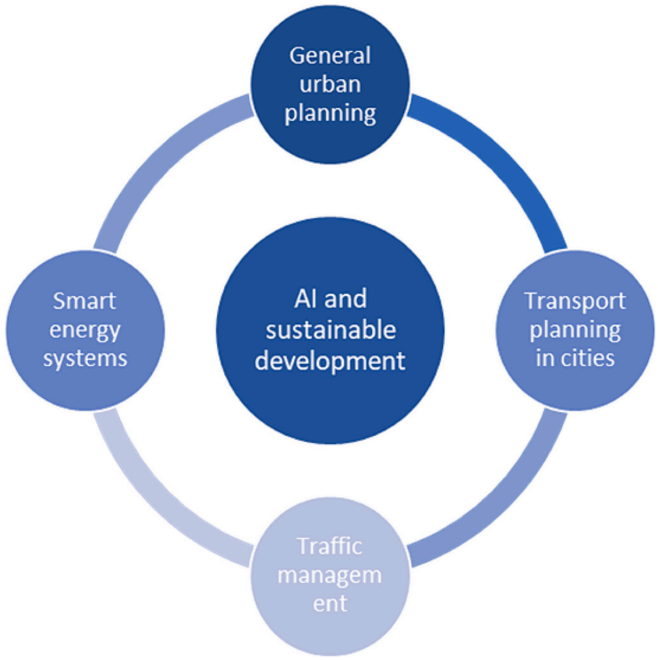

Fig. 2. Exemplified areas of intervention where AI is able to contribute to SDG 11.

4.2.1. AI in general urban planning

Regarding the use of AI to enhance the effectiveness of urban planning and design processes the literature has explored the potential applications of AI-related tools and geo-localized big data to address specific research challenges in this field (Table 2) (Kamrowska-Załuska, 2021). For instance, a study conducted by Yigitcanlar et al. (2020) centres on the perception and utilization of AI technologies in the context of urban planning and development in Australia. By analyzing location-based Twitter messages, they examined public sentiment and opinions regarding AI technologies and their relevance in urban planning. The research findings shed light on the public's attitudes towards AI in the context of urban development, providing valuable insights into how these technologies are perceived and integrated into urban planning practices in Australia. Samsurijan et al. (2022) presented a study that assessed the impact of AI on urban services in Malaysia. The study revealed that the success of AI in municipal services is closely tied to the level of information technology literacy among the urban population. This highlights the interplay between technological advancement and digital literacy in urban service enhancement.

The study by Yigitcanlar and Cugurullo (2020) focuses on how urban AI manages various aspects of cities, including transportation systems, urban infrastructure, and domains like traffic control, air quality monitoring, garbage collection, and energy management. The research provides insights into the evolving field of urban AI and its potential to contribute to smart and sustainable urban development. It highlights the symbiotic relationship between AI and urbanism, where AI technologies are critical in improving urban services and sustainability. Furthermore, the study conducted by Sanchez et al. (2023) reports the results of a national survey involving urban planners and their perspectives on AI adoption and associated concerns. This research offers a comprehensive understanding of how urban planning professionals view the adoption of AI technologies. The study provides valuable insights into the potential challenges and opportunities that urban planners face with integrating AI in their work. These perspectives are crucial for shaping the future of AI adoption in urban planning and design.

4.2.2. AI in transport planning

Traffic congestion is a major concern to urban planners. Table 3 highlights the cases of the applications of AI in transport planning. In Pakistan, it costs close to one million rupees daily (Cao & Wang, 2019; Khan et al., 2022). The City of Pittsburgh introduced a Scalable Urban Traffic Control (Surtrac) system in 2012 for real-time traffic light coordination based on AI and predictive data. It adapts traffic light sequencing plans in real-time at road intersections. A smart real-time urban vehicular road congestion estimation of traffic and clustering technique for urban vehicular roads was also simulated on various road maps in New Delhi, which indicates a significant reduction in travel time

Table 2
Case studies on AI in general urban planning.

Nature of the case study	Scope	Reference
Implications of AI-based tools and urban big data analytics in urban planning and design	This study discusses the implications of AI-based tools and urban big data analytics in urban planning and design. The study explores how AI-related tools and geo-localized big data can be used to solve specific research problems in urban planning and design. The findings provide insights for urban planners interested in utilizing AI and big data analytics in their practice.	Kamrowska-Załuska (2021)
Public perceptions of AI technologies in urban planning in Australia	It focuses on the perception and utilization of AI technologies in urban planning and development in Australia. The study examines public perceptions of AI technologies and their application areas through sentiment and content analyses of location-based Twitter messages. The findings shed light on how AI technologies are perceived and utilized in urban planning and development.	Yigitcanlar et al. (2020)
Influence of AI on urban services in Malaysia	This paper assesses the influence of AI on urban services in Malaysia. The study reviewed official documents and articles related to urban studies in Malaysia. The findings revealed that the development of global digital technology influences the upgrading of AI in urban services in Malaysia. Also, the success of AI in these municipal services is controlled by the rate of information technology literacy among the urban population.	Samsurijan et al. (2022)
Sustainability of AI from the lens of smart and sustainable cities	This study discusses how urban AI manages various aspects of cities, such as transport systems, urban infrastructure, and urban domains like traffic, air quality monitoring, garbage collection, and energy. The viewpoint also generates insights into emerging urban AI and the potential symbiosis between AI and smart and sustainable urbanism.	Yigitcanlar and Cugurullo (2020)
Analysis of AI concerns and expectations	It discusses the results of a national survey of urban planners about their perspectives on AI adoption and concerns.	Sanchez et al. (2023)

Table 3
Case studies on AI in transport planning in cities.

Nature of the case study	Scope	Reference
Road condition monitoring to identify road imperfections and irregularities	Captures initiatives by the Swedish government to foster smart cities and communities nationwide.	Englund et al. (2021)
Route optimization techniques that benefit from Google technology to suggest the best routes to road users and contribute to reducing traffic congestion, vehicle emissions, and traveling time.	*CrowdNavi*, an app, was discussed, and the solutions and challenges associated with operationalizing a crowdsourced navigation system were unpacked.	Fan et al. (2017)
Intelligent Park Monitoring helps drivers find parking slots in car parks and also helps park managers monitor park activities.	Examined the implications of motorists using AI in contexts such as retail malls, skyscrapers, fiestas, festivals, and hospitals, where parking spaces are limited.	Khan et al. (2022)
Smart Street Lights (SSL) used to detect crowded areas and dynamically adapt light intensity to improve security, reduce accidents, and save energy.	The scope of the study is global, with insights into the prevailing situation of light-emitting diode technology in smart public lighting systems in cities worldwide.	Patarroyo et al. (2019)
Smart real-time traffic congestion estimation and clustering technique for urban vehicular roads	The study methodology was employed in New Delhi in, India, covering several roadmaps. The result indicated a drastic reduction in travel time compared to other conventional techniques, such as path-finding methods.	Pattanaik et al. (2016)

Table 4
Case studies on AI in traffic management.

Nature of the case study	Scope	Reference
Development of a new empirically intelligent XGboost (EIXGB) that can monitor real-time public traffic management with high accuracy	EIXGB can integrate edge networks in public traffic management with higher accuracy and minimum error, contributing to auto-tune performance and adjust decisions with minimum delay	Alkinani et al. (2023)
4D trajectory prediction, involving conflict detection and resolution (CD&R) in Air traffic management (ATM)	Comparing the effectiveness of methods for conflict detection in ATM, demonstrating the development of AI to improve safety	Monteiro et al. (2023)
Enhanced traffic accident management approach based on Knowledge Discovery in Databases (KDD)	A case study of traffic accidents in Jordan is discussed, allowing for the identification of driver error as the main reason leading to accidents	Alzyoud (2023)
Analysis of the introduction of AI in the European Air traffic management (ATM)	Documenting the implications deriving from the challenges posed by AI at the level of 'control' in terms of ATM, at very different levels, from regulatory to operational frameworks	Stathis et al. (2022)
Focus on how eXplainable Artificial Intelligence in ATM (XAI) works	Systematic review analyzing the state of the art with AI and ATM, i.e., XAI	Degas et al. (2022)
Adaptive Neuro-Fuzzy Inference System (ANFIS) model was developed to estimate the extent of traffic emissions (NO_2 and PM_{10}) at intersections	Discusses the advantages of an ANFIS to promote better urban air quality through direct intervention in traffic management, facilitating city planners and decision-making in urban air quality.	Younes et al. (2020)

Table 5
Case studies on AI in smart energy systems.

Nature of the case study	Scope	Reference
An overview of the relevance of emerging information and communication technologies in the shift towards renewable energy and the development of intelligent energy systems.	Artificial intelligence (AI) technologies have shown their effectiveness in smart energy systems through extensive academic research and practical applications in various industries.	Zhao et al. (2023)
Global trends in 5G applications for smart buildings, along with research and testing carried out in 5G laboratories.	Singapore implements 5G communication technology in intelligent buildings to establish an optimally cost-effective system. The primary objective is to attain peak performance while minimizing investment expenditure.	Huseien and Shah (2022)
The introduction of smart energy management technologies is examined, along with a discussion on the obstacles encountered during the implementation process and the strategies employed to overcome them.	One more prospective direction for smart energy management involves leveraging artificial intelligence (AI) and machine learning (ML) to optimize energy consumption. These advanced technologies are capable of processing extensive datasets and offering valuable insights into consumption trends. This empowers cities to base their decisions on data, ultimately enhancing energy efficiency.	Pandiyan et al. (2023)
Use of artificial intelligence techniques in smart grid and power systems.	In this paper, a comprehensive examination of recent implementations of AI methodologies in four critical areas (namely, load prediction, evaluation of power grid stability, detection of faults, and addressing security concerns) is presented and discusses existing challenges, potential prospects, and the envisioned trajectory.	Omitaomu and Niu (2021)
A systematic review of recent literature investigates the research that has been done, focused on enhancing energy management systems for smart buildings through the application of artificial intelligence techniques.	Artificial intelligence techniques have the capability to model and comprehend various scenarios. They can be employed to create models for forecasting consumption, diagnosing situations, or discerning occupants' behavior, among other applications.	Aguilar et al. (2021)

(Pattanaik et al., 2016).

Researchers are increasingly exploring ways to detect roadway anomalies using AI, which identifies road imperfections and lets city managers decide quickly on necessary interventions (Khan et al., 2022). In this regard, Sweden has initiated a project that uses AI software called 3DAI City to manage roadside infrastructure and enhance efficient and sustainable transportation networks (SmartCitiesWorld, 2023). Olsson (2022) reports that Univrses, the organization that developed the smart city system, has created datasets that it uses to train AI models to understand multiple urban features that can be used to detect road works and damages. Saving time on the road is another important area of interest to city planners, road users, and researchers. Route optimization techniques have improved over the years and are increasingly used by road users for both direction and travel time optimization (Giannopoulos, 2004; Gipps et al., 2001; Zantalis et al., 2019). Route optimization technology suggests the best routes for specified user destinations and contributes to reducing traffic congestion, vehicle emissions, and travel time. This system mainly benefits from Google technology and crowdsourcing. Google Maps application, which is compatible with most modern mobile devices, integrates GPS, gyroscope sensors, and an accelerometer and has been quite helpful in this regard (Al-Dweik et al., 2017; Fan et al., 2017; Zantalis et al., 2019). Zantalis, et al. (2019, p.15) explain that "the end users' mobile devices can send anonymous information about their speed and location just by using the maps application. Google Maps can now suggest new routes based on traffic information in order to avoid congestion".

Smart Street Lights draws on the IoT infrastructure, sensors, and wireless communication systems (Dizon & Pranggono, 2022; Jia et al., 2018). This technology is already used in many cities, including Sheffield, Doncaster, and Edinburgh (Dizon & Pranggono, 2022). Some of the existing models help streetlamps detect crowded areas and determine how to dynamically adapt the intensity of their lights in ways that contribute to improving security, reducing accidents, and saving energy. Through its autonomous alarm and GPS monitoring system, the street light managers can also detect abnormal status, stolen and broken lamps, and speed up their maintenance processes. This has been implemented in Oslo, Norway (Jia et al., 2018; Suseendran et al., 2018; Patarroyo et al., 2019; Zantalis et al., 2019). According to Kabir et al. (2021, p.1), drivers in the U.S.A. tend to spend up to 17 h annually to find a space to park their cars; in Kuala Lumpur (Malaysia), drivers may need to spend up to 25 min daily waiting to find space to park their cars, while 58 % of drivers in New Delhi, 44 % in Bangalore, 43 % in Nairobi and 37 % in Milan have taken part in a fight or vocal argument over a parking space. These examples highlight the need for smart ways to solve car parking challenges. Thus, intelligent parking systems that use AI have been used in many cities to help drivers discover available parking spaces and provide progress reports on space occupation (Khan et al., 2022). Nota Inc. (2023) reports a successful experiment of smart parking in Milton Keynes by a South Korean start-up, Nota AI, which uses AI Camera technology to monitor parking in real-time. Sony image sensors with AI capability were tested in Rome (Ward-Foxton, 2021), and the Queen Elizabeth Olympic Park in London worked with Fyma (an AI company) to transform CCTV cameras into smart devices for the monitoring of the 560-acre park, including monitoring of users, bus stops and vehicles' waiting times (Shift, 2022).

4.2.3. AI in traffic management

In Table 4, several case studies involving the use of AI in the context of traffic management are presented.

Advances in computer and communication technologies, as well as the rising use of IoT and AI technologies, have prepared the way for enormous enhancements in modern transportation systems, contributing to the advancement of modern traffic management and SDG 11. In consideration of this, Alkinani et al. (2023) have conceived a logistic empirically intelligent XGboost (EIXGB) to manage real-time traffic at the edge networks, collecting and processing current traffic data, which is then used to feed the machine learning, with the system proving to be very efficient. The accuracy over the real-time traffic management dataset was 87–97 %, contributing to a more precise decision-making process at the public traffic management systems level. The effectiveness of intelligent transportation systems depends on decision support for real-time traffic management. To determine the main causes of traffic accidents and their consequences on different types of accidents, a case study of traffic accidents in Jordan was undertaken by Alzyoud (2023), using actual data from the Public Security Directorate Records and the Department of Statistics between 2016 and 2020. Driver error is the main reason for the increasing number of accidents and injuries. The authors report that using big data and Knowledge Discovery in Databases (KDD) techniques can significantly improve existing traffic accident management practices, promoting the development of new policies and regulations to improve road safety and reduce economic and environmental impacts. While the analysis of traffic management per se constitutes an important evaluation in terms of all the variables being considered crucial in this respect, the integration of AI in the context of traffic management is an important synergy in the current times in order to assess the urban air quality. Younes et al. (2020) managed to use an Adaptive Neuro-Fuzzy Inference System (ANFIS) to analyse the extent of traffic emissions (NO_2 and PM_{10}). The hybrid model created revealed that delaying traffic at certain intersections was able to contribute to significantly reducing NO_2 and PM_{10} emissions, translating into better urban air quality and unveiling the significance of using AI to contribute to intervening at the level of traffic management and improving the quality of air in the urban context. Thus, modelling environmental pollutants, integrated with traffic management, contributes to improving air quality and reducing pollution levels through suggested AI actions that intervene in traffic congestion at intersections.

Air traffic management (ATM) is another area that can be challenged through the intervention of AI. According to Stathis et al. (2022), a pilot in a cockpit is the perfect example of the fruitful collaboration between humans and machines, with ATM considered as the environment in the flight Joint Cognitive System (JCS), i.e., pilot + automation. With AI spreading fast, in both air and ground, these authors call attention to the opportunities/challenges that must be taken seriously. Examples involving innovative technologies have implications at the regulatory and operational levels, and the question of who/what is 'in control' is now more pertinent. The same authors guided us through a specific set of challenges involving AI and the European ATM: i. political/regulatory; ii. Air Navigation Service Provider (ANSP)/business; iii. technical; iv. operational; and v. Air Traffic Controllers (ATCOs) levels. All the issues raised are translated into mainly two questions, i.e., the 'in control' already mentioned as well as how to amplify it; within this new range of possibilities promoted by AI evolution, interesting examples can be considered in the scope of sustainable development. An interesting area of research in terms of ATM involves trajectory prediction and conflict detection and resolution (CD&R). In order to assess this, Monteiro et al. (2023) studied different simulation scenario databases, resulting in the development of a new computational solution for CD&R in 4D trajectories that includes a trajectory predictor, decision tree pruning approach, and specifically designed big data databases, supporting the decision-making of air traffic stakeholders - not replacing ATCOs, but allowing human-machine integration to assist intelligent air transportation, which is a significant contribution of AI to ATM safety and sustainable development. ATM will become more and more complex in the upcoming decades. It has to do with aviation growth and complexity, as advocated by Degas et al. (2022). As just mentioned, AI poses challenges and has not yet reached end-users regarding ATM. The roles of air routes, airport management, aircrafts, and airlines in the safety and fluidity of air traffic will all need to be considered in the scope of how ATM eXplainable Artificial Intelligence (XAI) works, in order to guarantee that air traffic is the safest possible, as it is necessary to further invest in the predictive and prescriptive characteristics of the variables analysed, beyond the more commonly reported descriptive features.

4.2.4. AI in smart energy systems

Regarding the relevance of emerging information and communication technologies in the shift towards renewable energy and the development of intelligent energy systems, (AI) technologies have the potential to enhance the effectiveness and efficiency of energy transition planning and the management of smart energy systems, especially when dealing with huge numbers of datasets (Choney, 2022). Table 5 presents cases on the use of AI in smart energy systems. According to Zhao et al. (2023), (AI) technologies have shown their effectiveness in smart energy systems through extensive academic research and practical applications in various industries. The authors showed that optimization techniques could reduce the economic expenses associated with operating energy systems. Time series and sequence-to-sequence learning have shown great potential for integration into smart sensors, potentially leading to scalable solutions for analyzing energy usage and providing accurate forecasts for smart energy systems.

Smart energy systems can also be part of buildings and are defined as smart buildings, a concept based on energy efficiency combined with smart grids - intelligent management systems incorporate functionalities for storing and analyzing large volumes of data. Consequently, when applied in buildings, they can enhance energy management, as applied in Singapore (Huseien & Shah, 2022). Another advantage of smart buildings is that because they are designed to efficiently arrange information resources, they receive a minimum reasonable return on investment, highlighting the characteristics of eco-friendliness, comfort, efficiency, and energy-saving features (Fan et al., 2019). Allam and Dhunny (2019) affirm that artificial intelligence will soon be indispensable for managing smart buildings, especially with the integration of 5G technology, aiming to make buildings more adaptable rather than simply automated. Smart cities generate substantial data; artificial intelligence - specifically through machine-to-machine communication processing - plays a crucial role in analyzing it to further enhance decision-making, helping with predictive and preventive measures while providing a comprehensive approach to system settings.

Cities have a major challenge in managing their energy usage, significantly contributing to urban carbon emissions. To promote the development of diverse technological advancements in intelligent energy management to help environmental sustainability, encouraging prospects for optimizing energy usage and reducing expenses. Smart energy management involves artificial intelligence and machine learning to optimize energy consumption, process extensive datasets and offer valuable insights into consumption trends. This empowers cities to base their decisions on data, ultimately enhancing energy efficiency (Pandiyan et al., 2023). Furthermore, artificial intelligence techniques can model and comprehend various scenarios. They can be employed to create models for forecasting consumption, diagnosing situations, or discerning occupants' behavior, among other applications (Aguilar et al., 2021).

It is becoming more apparent to apply artificial intelligence techniques in the smart grid, which can be explained by the AI techniques that use extensive datasets to develop intelligent machines capable of performing tasks that typically demand human intelligence with speed and accuracy. However, there are instances where AI may not entirely replace human grid operators. Despite the potential for AI systems to offer increased precision, reliability, and comprehensiveness, numerous challenges persist in effectively implementing AI techniques within the smart grid. In fact, the primary challenges are regarding data privacy and security, along with addressing the "black box" nature of certain AI methods to foster a more human-centred approach in the design of AI solutions (Omitaomu & Niu, 2021).

5. Conclusions

This paper has explored the role of AI in fostering sustainable cities and communities (SDG 11) by advancing the principles of sustainability and social progress outlined in the SDGs. The main contributions of this paper lie in its comprehensive exploration of the role of AI in advancing SDG 11 for sustainable cities and communities. By thoroughly examining various applications and implications of AI within this framework, the paper demonstrates how AI can foster sustainable development, emphasizing inclusivity, safety, resilience, and sustainability. It provides detailed insights into the potential applications of AI, such as optimizing energy use, streamlining waste management, improving traffic flow, and enhancing environmental monitoring.

The potential applications of AI, as showcased on this paper, are manifold. AI can optimize energy use in buildings and homes, reducing consumption and costs. It can also help to streamline waste collection and recycling processes. For instance, AI-powered sorting systems can more efficiently separate recyclable materials, and predictive analytics can optimize collection routes and schedules. In the field of traffic management, AI can be used to improve traffic flow, reduce congestion, and lower emissions, and support the development of smart mobility solutions. Moreover, the paper highlights the environmental advantages of AI in predicting water demand, managing water distribution, monitoring air quality, and contributing to macro-level planning for more sustainable urban environments. While acknowledging the significant advantages of AI in urban settings, the paper emphasizes its role as a tool to assist human decision-making, stressing the importance of ethical considerations, addressing biases, and ensuring privacy in the implementation of AI systems in urban planning.

While this study offers valuable insights into the positive contributions of AI to urban sustainability, it is important to recognize the limitations in the depth of analysis on ethical considerations, potential risks, and the practical aspects of achieving collaborative efforts. In acknowledging the negative aspects of AI that can potentially compromise the sustainability of cities, it's crucial to highlight specific areas where the paper could benefit from a more nuanced exploration. Firstly, the ethical implications of AI implementation, such as biases in algorithms and decision-making processes, are briefly mentioned. However, a more in-depth examination of how these biases can perpetuate existing inequalities in urban settings and hinder social progress would contribute to a more comprehensive discussion. The paper could benefit from a detailed examination of the criteria and benchmarks used to assess the performance of AI applications in comparison to traditional methods. This includes metrics for accuracy, efficiency, and effectiveness in addressing specific urban challenges. Discussing the complexities of measuring success when considering the dynamic and context-specific nature of urban environments would also contribute to a more nuanced understanding of AI effectiveness.

Looking towards the future, the study advocates for collaborative efforts among urban planners, policymakers, and AI experts to fully harness the potential of AI in improving urban planning processes. By fostering inclusive, ethically acceptable, and privacy-respecting implementations, this collaboration can contribute significantly to the realization of SDG 11, ensuring sustainable, resilient, and inclusive cities for the growing global urban population. Based on the conclusions drawn from this study, several suggestions for future studies to further explore and advance the intersection of AI and SDG 11 for sustainable cities and communities could address the following aspects:

- *Human-Centric AI Integration*. Investigate methods to enhance the human-AI interaction in urban planning.
- *Algorithmic Fairness and Bias Mitigation*. Conduct research on developing and implementing algorithms that prioritize fairness and mitigate biases in urban planning decisions.
- *Privacy and Data Security in AI Systems*. Explore strategies to enhance the privacy and data security aspects of AI systems used in urban planning.
- *Community Engagement and Inclusivity*. Investigate how to incorporate community input and perspectives effectively in AI-driven urban planning processes.
- *AI for Social Equity*. Examine ways in which AI can be leveraged to address social equity challenges in urban areas.
- *Long-Term Environmental Impact Assessment*. Investigate the long-term environmental impact of AI technologies used in sustainable urban development.
- *Policy Frameworks and Governance Models*. Research optimal policy frameworks and governance models for the responsible implementation of AI in urban planning.
- *Cross-Disciplinary Collaboration*. Encourage collaborative research efforts involving urban planners, policymakers, AI experts, environmental scientists, and social scientists.
- *Scalability and Adaptability of AI Solutions*. Evaluate the scalability and adaptability of AI-driven solutions across different urban contexts and regions.
- *Impact Assessment of AI in Urban Planning*. Conduct comprehensive studies to assess the impact of AI implementations in urban planning on achieving SDG 11.

CRediT authorship contribution statement

Walter Leal Filho: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Marcellus Forh Mbah:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation. **Maria Alzira Pimenta Dinis:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Laís Viera Trevisan:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation. **Deborah de Lange:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation. **Ashish Mishra:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation. **Bianca Rebelatto:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation. **Tarek Ben Hassen:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation. **Yusuf A. Aina:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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References

Acharya, G., Cassou, E., Jaffee, S., & Ludher, E. K. (2021). *RICH food, smart city: How building reliable, inclusive, competitive, and healthy food systems is smart policy for urban Asia*. Washington, DC.

Aguilar, J., Garces-Jimenez, A., Moreno, M. D., & García, R. (2021). A systematic literature review on the use of artificial intelligence in energy self-management in smart buildings. *Renewable and Sustainable Energy Reviews, 151*, Article 111530. https://doi.org/10.1016/j.rser.2021.111530

Ahmed, I., Zhang, Y., Jeon, G., Lin, W., Khosravi, M. R., & Qi, L. (2022). A blockchain- and artificial intelligence-enabled smart IoT framework for sustainable city. *International Journal of Intelligent Systems, 37*(9), 6493–6507. https://doi.org/10.1002/int.22852

Aina, Y. A., Abubakar, I. R., Almulhim, A. I., Dano, U. L., Maghsoodi Tilaki, M. J., & Dawood, S. R. (2023). Digitalization and smartification of urban services to enhance urban resilience in the post-pandemic era: The case of the Pilgrimage City of Makkah. *Smart Cities, 6*(4), 1973–1995.

AL-Dosari, K., Fetais, N., & Kucukvar, M. (2022). Artificial intelligence and cyber defense system for banking industry: A qualitative study of AI applications and challenges. *Cybernetics and Systems*, 1–29.

Al-dousari, A. E., Mishra, A., & Singh, S. (2023). Land use land cover change detection and urban sprawl prediction for Kuwait metropolitan region, using multi-layer perceptron neural networks (MLPNN). *The Egyptian Journal of Remote Sensing and Space Sciences, 26*(2), 381–392. https://doi.org/10.1016/j.ejrs.2023.05.003

Al-Dweik, A., Muresan, R., Mayhew, M., & Lieberman, M. (2017, April). IoT-based multifunctional scalable real-time enhanced road side unit for intelligent transportation systems. In *In 2017 IEEE 30th Canadian conference on electrical and computer engineering (CCECE)* (pp. 1–6). IEEE.

Alizadeh, B., & Hitchmough, J. (2019). A review of urban landscape adaptation to the challenge of climate change. *International Journal of Climate Change Strategies and Management, 11*(2), 178–194. https://doi.org/10.1108/IJCCSM-10-2017-0179

Alkinani, M. H., Almazroi, A. A., Adhikari, M., & Menon, V. G. (2023). Artificial intelligence-empowered logistic traffic management system using empirical intelligent XGBoost technique in vehicular edge networks [article; early access]. *IEEE Transactions on Intelligent Transportation Systems, 24*(4), 4499–4508. https://doi.org/10.1109/tits.2022.3145403

Allam, Z., & Dhunny, Z. A. (2019). On big data, artificial intelligence and smart cities. *Cities, 89*, 80–91.

Alshuwaikhat, H. M., Aina, Y. A., & Binsaedan, L. (2022). Analysis of the implementation of urban computing in smart cities: A framework for the transformation of Saudi cities. *Heliyon, 8*(10), Article e11138.

Alzyoud, F. (2023). Improved model for traffic accident management system using KDD and big data: Case study Jordan [Article]. *International Journal of Computers Communications & Control, 18*(3), Article 5006. https://doi.org/10.15837/ijccc.2023.3.5006

Arfat, Y., Aqib, M., Mehmood, R., Albeshri, A., Katib, I., Albogami, N., & Alzahrani, A. (2017). Enabling smarter societies through mobile big data fogs and clouds. *Procedia Computer Science, 109*, 1128–1133.

Barns, S. (2016). Mine your data: Open data, digital strategies and entrepreneurial governance by code. *Urban Geography, 37*(4), 554–571.

Batty, M. (2018). Artificial intelligence and smart cities. *Environment and Planning B: Urban Analytics and City Science, 45*(1), 3–6. https://doi.org/10.1177/2399808317751169

Batty, M. (2021). Planning education in the digital age. *Environment and Planning B: Urban Analytics and City Science, 48*(2).

Beck, D., Ferasso, M., Storopoli, J., & Vigoda-Gadot, E. (2023). Achieving the sustainable development goals through stakeholder value creation: Building up smart sustainable cities and communities. *Journal of Cleaner Production, 399*(December 2022), 1–11. https://doi.org/10.1016/j.jclepro.2023.136501

Bedi, P., Goyal, S. B., Rajawat, A. S., Shaw, R. N., & Ghosh, A. (2022). Application of AI/IoT for smart renewable energy management in smart cities. *AI and IoT for Smart City Applications*, 115–138.

Belkhir, L., & Elmeligi, A. (2018). Assessing ICT global emissions footprint: Trends to 2040 & recommendations. *Journal of Cleaner Production, 177*, 448–463. https://doi.org/10.1016/j.jclepro.2017.12.239

Ben Hassen, T., & El Bilali, H. (2022). Impacts of the Russia-Ukraine war on global food security: Towards more sustainable and resilient food systems? *Foods, 11*, 2301. https://doi.org/10.3390/foods11152301

Bettencourt, L., & West, G. (2010). A unified theory of urban living. *Nature, 467*(7318), 912–913. https://doi.org/10.1038/467912a

Bibri, S. E., & Krogstie, J. (2020). The emerging data–driven Smart City and its innovative applied solutions for sustainability: The cases of London and Barcelona. *Energy Informatics, 3*(1), 5.

Bibri, S. E., Krogstie, J., Kaboli, A., & Alahi, A. (2024). Smarter eco-cities and their leading-edge artificial intelligence of things solutions for environmental sustainability: A comprehensive systematic review. *Environmental Science and Ecotechnology, 19*, Article 100330.

Braun, T., Fung, B. C., Iqbal, F., & Shah, B. (2018). Security and privacy challenges in smart cities. *Sustainable Cities and Society, 39*, 499–507.

Buonomano, A., Barone, G., & Forzano, C. (2023). Latest advancements and challenges of technologies and methods for accelerating the sustainable energy transition. *Energy Reports, 9*, 3343–3355. https://doi.org/10.1016/j.egyr.2023.02.015

Cao, W., & Wang, J. (2019, February). Research on traffic flow congestion based on Mamdani fuzzy system. In *, Vol. 2073, No. 1. AIP conference proceedings*. AIP Publishing.

Caragliu, A., & Del Bo, C. F. (2023). Smart cities and the urban digital divide. *npj Urban Sustainability, 3*(1), 43.

Chipofya, M., Karamesouti, M., Schultz, C., & Schwering, A. (2020). Local domain models for land tenure documentation and their interpretation into the LADM. *Land Use Policy, 99*, Article 105005.

Clement, J., Ruysschaert, B., & Crutzen, N. (2023). Smart city strategies – A driver for the localization of the sustainable development goals? *Ecological Economics, 213*(July), Article 107941. https://doi.org/10.1016/j.ecolecon.2023.107941

Coeckelbergh, M. (2020). *AI ethics*. Boston: MIT Press Essential Knowledge series.

Coeckelbergh, M. (2021). AI for climate: Freedom, justice, and other ethical and political challenges. *AI and Ethics, 1*, 67–72. https://doi.org/10.1007/s43681-020-00007-2

Contreras-Figueroa, V., Montané-Jiménez, L. G., Cepero, T., Benítez-Guerrero, E., & Mezura-Godoy, C. (2021). *October). Information visualization in adaptable dashboards for smart cities: A systematic review* (pp. 34–43). IEEE.

Cook, D. (2023, May 16). *Toronto's Eglinton Crosstown LRT project could be delayed again by construction consortium's legal challenge, transit agency says*. The Globe and Mail. https://www.theglobeandmail.com/canada/article-eglinton-crosstown-lrt-metrolinx/.

Creutzig, F., Franzen, M., Moeckel, R., Heinrichs, D., Nagel, K., Nieland, S., & Weisz, H. (2019). Leveraging digitalization for sustainability in urban transport. *Global Sustainability, 2*, Article e14.

Cugurullo, F. (2020). Urban artificial intelligence: From automation to autonomy in the smart city. *Frontiers in Sustainable Cities, 2*, 38.

Cugurullo, F. (2021). *Frankenstein urbanism: Eco, smart and autonomous cities, artificial intelligence and the end of the city*. Routledge.

Cugurullo, F., Caprotti, F., Cook, M., Karvonen, A., McGuirk, P., & Marvin, S. (2023). The rise of AI urbanism in post-smart cities: A critical commentary on urban artificial intelligence. *Urban Studies, 61*(6), 1168–1182. https://doi.org/10.1177/00420980231203386

Cullen-Knox, C., Eccleston, R., Haward, M., Lester, E., & Vince, J. (2017). Contemporary challenges in environmental governance: Technology, governance and the social licence. *Environmental Policy and Governance, 27*, 3–13. https://doi.org/10.1002/eet.1743

Dai, L., Derudder, B., & Liu, X. (2018). Transport network backbone extraction: A comparison of techniques. *Journal of Transport Geography, 69*, 271–281.

de Lange, D. (2023). Sustainable transportation for the climate: How do transportation firms engage in cooperative public-private partnerships? *Sustainability, 15*(11), 8682.

de Lange, D. E. (2020). Responsible artificial intelligence and partnerships for the goals. In W. Leal Filho, A. Azul, L. Brandli, A. Lange Salvia, & T. Wall (Eds.), *Partnerships for the goals. Encyclopedia of the UN sustainable development goals*. Cham: Springer. https://doi.org/10.1007/978-3-319-71067-9_77-1.

de Lange, D. E. (2021). International isomorphism, sustainable innovation and wealth for OECD cities. *Journal of Urban Affairs, 43*(9), 1285–1309.

Degas, A., Islam, M. R., Hurter, C., Barua, S., Rahman, H., Poudel, M., … Aricó, P. (2022). A survey on artificial intelligence (AI) and eXplainable AI in air traffic management: Current trends and development with future research trajectory [article]. *Applied Sciences, 12*(3), Article 1295. https://doi.org/10.3390/app12031295

Degbelo, A., Granell, C., Trilles, S., Bhattacharya, D., Casteleyn, S., & Kray, C. (2016). Opening up smart cities: Citizen-centric challenges and opportunities from GIScience. *ISPRS International Journal of Geo-Information, 5*(2), 16.

Choney, S. (2022). How one of the world's largest wind companies is using AI to capture more energy. . (Accessed 10 April 2023). Available: https://news.microsoft.com/europe/features/winds-of-change-how-one-of-the-worlds-largest-wind-companies-is-using-ai-to-capture-more-energy/.

Department of Economic and Social Affairs. (n.d.). Make cities and human settlements inclusive, safe, resilient and sustainable. United Nations. Retrieved 18 Jun 2023 from https://sdgs.un.org/goals/goal11.

Dionisio, M., De Souza Junior, S. J., Paula, F., & Pellanda, P. C. (2023). The role of digital social innovations to address SDGs: A systematic review. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-023-03038-x

Dizon, E., & Pranggono, B. (2022). Smart streetlights in Smart City: A case study of Sheffield. *Journal of Ambient Intelligence and Humanized Computing*, 1–16.

Englund, C., Aksoy, E. E., Alonso-Fernandez, F., Cooney, M. D., Pashami, S., & Åstrand, B. (2021). AI perspectives in Smart Cities and Communities to enable road vehicle automation and smart traffic control. *Smart Cities, 4*(2), 783–802.

Fan, J. R., et al. (2019). Energy saving-motion activated smart fan design and implementation. *International Journal of Engineering Creativity & Innovation, 1*(1), 24–32.

Fan, X., Liu, J., Wang, Z., Jiang, Y., & Liu, X. (2017). Crowdsourced road navigation: Concept, design, and implementation. *IEEE Communications Magazine, 55*(6), 126–128.

Fatemidokht, H., Rafsanjani, M. K., Gupta, B. B., & Hsu, C. H. (2021). Efficient and secure routing protocol based on artificial intelligence algorithms with UAV-assisted for vehicular ad hoc networks in intelligent transportation systems. *IEEE Transactions on Intelligent Transportation Systems, 22*(7), 4757–4769.

Foth, N., Manaugh, K., & El-Geneidy, A. M. (2013). Towards equitable transit: Examining transit accessibility and social need in Toronto, Canada, 1996–2006. *Journal of Transport Geography, 29*, 1–10.

Fuso Nerini, F., Slob, A., Engström, R. E., & Trutnevyte, E. (2019). A research and innovation agenda for zero-emission European cities. *Sustainability, 11*, 1692. https://doi.org/10.3390/su11061692

Gaigné, C., Riou, S., & Thisse, J. F. (2012). Are compact cities environmentally friendly? *Journal of Urban Economics, 72*(2–3), 123–136.

Geller, H., Schaeffer, R., Szklo, A., & Tolmasquim, M. (2004). Policies for advancing energy efficiency and renewable energy use in Brazil. *Energy Policy, 32*(12), 1437–1450.

Ghobakhloo, M. (2020). Industry 4.0, digitization, and opportunities for sustainability. *Journal of Cleaner Production, 252*, Article 119869. https://doi.org/10.1016/j.jclepro.2019.119869

Giannopoulos, G. A. (2004). The application of information and communication technologies in transport. *European Journal of Operational Research, 152*(2), 302–320.

Gipps, P. G., Gu, K. Q., Held, A., & Barnett, G. (2001). New technologies for transport route selection. *Transportation Research Part C: Emerging Technologies, 9*(2), 135–154.

Gupta, S., & Degbelo, A. (2023). An empirical analysis of AI contributions to sustainable cities (SDG 11). In *The ethics of artificial intelligence for the sustainable development goals* (pp. 461–484). Cham: Springer International Publishing.

Helber, P., Bischke, B., Dengel, A., & Borth, D. (2019). Eurosat: A novel dataset and deep learning benchmark for land use and land cover classification. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 12*(7), 2217–2226.

Hemphill, T. A. (2020). The innovation governance dilemma: Alternatives to the precautionary principle. *Technology in Society, 63*, 101381.

Huang, H., Ogbodo, M., Wang, Z., Qiu, C., Hisada, M., & Abdallah, A. B. (2021, January). Smart energy management system based on reconfigurable AI chip and electrical vehicles. In *2021 IEEE international conference on big data and smart computing (BigComp)* (pp. 233–238).

Huseien, F. G., & Shah, W. K. (2022). A review on 5G technology for smart energy management and smart buildings in Singapore. *Energy and AI, 7*, Article 100116. https://doi.org/10.1016/j.egyai.2021.100116

International Energy Agency. (2017). Digitalization and energy – Analysis. Paris https://www.iea.org/reports/digitalisation-and-energy. (Accessed 3 March 2024).

Jia, G., Han, G., Li, A., & Du, J. (2018). SSL: Smart street lamp based on fog computing for smarter cities. *IEEE Transactions on Industrial Informatics, 14*(11), 4995–5004.

Joubari, O. E., Othman, J. B., & Vèque, V. (2022). Markov chain mobility model for multi-lane highways. *Mobile Networks and Applications, 27*, 1286–1298. https://doi.org/10.1007/s11036-021-01893-4

Kabir, A. T., Saha, P. K., Hasan, M. S., Pramanik, M., Ta-Sin, A. J., Johura, F. T., & Hossain, A. M. (2021, June). An IoT based intelligent parking system for the unutilized parking area with real-time monitoring using mobile and web application. In *In 2021 international conference on intelligent technologies (CONIT)* (pp. 1–7). IEEE.

Kamrowska-Załuska, D. (2021). Impact of AI-based tools and urban big data analytics on the design and planning of cities. *Land, 10*(11), 1–19. https://doi.org/10.3390/land10111209

Khan, S., Adnan, A., & Iqbal, N. (2022, July). Applications of artificial intelligence in transportation. In *2022 international conference on electrical, computer and energy technologies (ICECET)* (pp. 1–6). IEEE.

Khozema, Z. (2023, March 21). A paved greenbelt will kneecap Ontario's economy and food security, expert says. *National Observer*. Retrieved June 26, 2023, from https://www.nationalobserver.com/2023/03/21/analysis/paved-greenbelt-kneecap-ontario-economy-food-security-expert-says.

Klopp, J. M., & Petretta, D. L. (2017). The urban sustainable development goal: Indicators, complexity and the politics of measuring cities. *Cities, 63*, 92–97. https://doi.org/10.1016/j.cities.2016.12.019

Kolesnichenko, O., Mazelis, L., Sotnik, A., Yakovleva, D., Amelkin, S., Grigorevsky, I., & Kolesnichenko, Y. (2021). Sociological modeling of smart city with the implementation of UN sustainable development goals. *Sustainability Science, 16*(2), 581–599. https://doi.org/10.1007/s11625-020-00889-5

Larson, T. D., & Rao, K. (1984). Breaking out for transportation progress: Policy responses to investment stalemate. *Transportation Research Part A: General, 18*(2), 141–149.

Leal Filho, W., Eustachio, J. H. P. P., Danila, A., Dinis, M. A. P., Salvia, A. L., Cotton, D. R. E., … Dibbern, T. (2023). *Using data science for sustainable development in higher education*. in press. John Wiley & Sons Ltd.. https://doi.org/10.1002/sd.2638.

Leal Filho, W., Vidal, D. G., Chen, C., Petrova, M., Dinis, M. A. P., Yang, P., … Neiva, S. (2022). An assessment of requirements in investments, new technologies and infrastructures to achieve the SDGs [research]. *Environmental Sciences Europe, 34*, 1–17. Article 58 https://doi.org/10.1186/s12302-022-00629-9.

Leal Filho, W., Viera Trevisan, L., Simon Rampasso, I., Anholon, R., Pimenta Dinis, M. A., Londero Brandli, L., … Mazutti, J. (2023). When the alarm bells ring: Why the UN sustainable development goals may not be achieved by 2030. *Journal of Cleaner Production, 407*, Article 137108. https://doi.org/10.1016/j.jclepro.2023.137108

Leal Filho, W., Yang, P., Eustachio, J. H. P. P., Azul, A. M., Gellers, J. C., Gielczyk, A., … Kozlova, V. (2023). Deploying digitalisation and artificial intelligence in sustainable development research. *Environment, Development and Sustainability, 25*(6), 4957–4988. https://doi.org/10.1007/s10668-022-02252-3

Lin, Y., & Yu, Z. (2023). A bibliometric analysis of artificial intelligence chatbots in educational contexts. *Interactive Technology and Smart Education*. https://doi.org/10.1108/ITSE-12-2022-0165. Vol. ahead-of-print No. ahead-of-print.

Liu, J., Zhao, W., & Xu, C. (2021). An efficient on-ramp merging strategy for connected and automated vehicles in multi-lane traffic. *IEEE Transactions on Intelligent Transportation Systems, 23*(6), 5056–5067.

Lu, C., Liu, J., Liu, Y., & Liu, Y. (2019). Intelligent construction technology of railway engineering in China. *Frontiers of Engineering Management, 6*, 503–516.

Macrorie, R., Marvin, S., & While, A. (2021). Robotics and automation in the city: A research agenda. *Urban Geography, 42*(2), 197–217.

Mądziel, M., Campisi, T., Jaworski, A., Kuszewski, H., & Woś, P. (2021). Assessing vehicle emissions from a multi-lane to turbo roundabout conversion using a microsimulation tool. *Energies, 14*, 4399. https://doi.org/10.3390/en14154399

Malla, M. K., & Arya, D. S. (2023). Event-based extreme precipitation variability analysis over a part of the Hindu Kush Himalayan region. *International Journal of Climatology, 43*(9), 4196–4219. https://doi.org/10.1002/joc.8082

Marr, B. (2017). *What is the Internet of Things (IoT) and how will it change our world?* Forbes. Retrieved February 9, 2024, from https://www.bernardmarr.com/default.asp?contentID=964.

Marsal-Llacuna, M. L. (2020). The people's smart city dashboard (PSCD): Delivering on community-led governance with blockchain. *Technological Forecasting and Social Change, 158*, Article 120150.

Mishra, A., & Arya, D. S. (2020). Development of decision support system (DSS) for urban flood management: A review of methodologies and results. *World Environmental and Water Resources Congress, 2020*, 60–72. https://doi.org/10.1061/9780784482988.007

Mishra, A., & Singh, D. (2023). Assessment of land-use land-cover dynamics and urban heat island effect of Dehradun city, North India: A remote sensing approach. *Environment, Development and Sustainability, 0123456789*. https://doi.org/10.1007/s10668-023-03558-

Mishra, K. N., & Chakraborty, C. (2020). A novel approach toward enhancing the quality of life in smart cities using clouds and IoT-based technologies. In M. Farsi, A. Daneshkhah, A. Hosseinian-Far, & H. Jahankhani (Eds.), *Digital Twin Technologies and Smart Cities* (pp. 19–35). Cham: Springer. https://doi.org/10.1007/978-3-030-18732-3_2.

Mishra, S., & Tyagi, A. K. (2022). The role of machine learning techniques in internet of things-based cloud applications. *Artificial Intelligence-based Internet of Things Systems*, 105–135.

Mohanty, S. P., Choppali, U., & Kougianos, E. (2016). Everything you wanted to know about smart cities: The internet of things is the backbone. *IEEE Consumer Electronics Magazine, 5*(3), 60–70.

Monteiro, C. S., Costa, C., Pina, A., Santos, M. Y., & Ferrão, P. (2018). An urban building database (UBD) supporting a smart city information system. *Energy and Buildings, 158*, 244–260.

Monteiro, L. B., Ribeiro, V. F., Garcia, C. P., Rocha Filho, G. P., & Li, W. (2023). 4D trajectory conflict detection and resolution using decision tree pruning method [article]. *IEEE Latin America Transactions, 21*(2), 277–287. https://doi.org/10.1109/tla.2023.10015220

Murphy, R. R. (2018). Smart houses and domotics. *Science robotics, 3*(24), Article eaav6015.

Musango, J. K., Currie, P., Smit, S., & Kovacic, Z. (2020). Urban metabolism of the informal city: Probing and measuring the 'unmeasurable' to monitor Sustainable Development Goal 11 indicators. *Ecological Indicators, 119*, 1–14. https://doi.org/10.1016/j.ecolind.2020.106746

Mustak, S., Baghmar, N. K., Singh, S. K., & Srivastava, P. K. (2022). Multi-scenario based urban growth modeling and prediction using earth observation datasets towards urban policy improvement. *Geocarto International*, 1–29.

Nasir, O., Javed, R. T., Gupta, S., Vinuesa, R., & Qadir, J. (2023). Artificial intelligence and sustainable development goals nexus via four vantage points. *Technology in Society, 72*, Article 102171. https://doi.org/10.1016/j.techsoc.2022.102171

Nishant, R., Kennedy, M., & Corbett, J. (2020). Artificial intelligence for sustainability: Challenges, opportunities, and a research agenda. *International Journal of Information Management, 53*, Article 102104. https://doi.org/10.1016/j.ijinfomgt.2020.102104

NOAA. (2021). *New dust forecast model excels in predicting December's dust storms*. Air Resources Laboratory. https://www.arl.noaa.gov/news-pubs/arl-news-stories/fengsha/. December 21, accessed online June 25, 2023.

Nordgren, A. (2023). Artificial intelligence and climate change: Ethical issues. *Journal of Information, Communication and Ethics in Society, 21*, 1–15. https://doi.org/10.1108/JICES-11-2021-0106

Nota Inc.. (2023). Nota AI™'s AI Parking PoC in Milton Keynes - Intelligent Transport. https://www.intelligenttransport.com/transport-articles/144972/nota-ais-ai-parking-poc-in-milton-keynes/.. (Accessed 12 July 2023).

Olsson, T. (2022). *Road data lab–Creating an open data ecosystem*.

Omitaomu, O. A., & Niu, H. (2021). Artificial intelligence techniques in smart grid: A survey. *Smart Cities, 4*, 548–568. https://doi.org/10.3390/smartcities4020029

Owusu, M., Kuffer, M., Belgiu, M., Grippa, T., Lennert, M., Georganos, S., & Vanhuysse, S. (2021). Towards user-driven earth observation-based slum mapping. *Computers, Environment and Urban Systems, 89*, Article 101681.

Palmini, O., & Cugurullo, F. (2023). Charting AI urbanism: Conceptual sources and spatial implications of urban artificial intelligence. *Discover Artificial Intelligence, 3*(1), 15.

Pandey, B., Brelsford, C., & Seto, K. C. (2022). Infrastructure inequality is a characteristic of urbanization. *Proceedings of the National Academy of Sciences, 119*(15), Article e2119890119.

Pandiyan, P., Saravanan, S., Usha, K., Kannadasan, R., Alsharif, H. M., & Kim, M. (2023). Technological advancements toward smart energy management in smart cities. *Energy Reports, 10*, 648–677. https://doi.org/10.1016/j.egyr.2023.07.021

Parthasarathy, D. (2018). Inequality, uncertainty, and vulnerability: Rethinking governance from a disaster justice perspective. *Environment and Planning E: Nature and Space, 1*(3), 422–442.

Parveen, S., Chadha, R. S., Noida, C., Kumar, I. P., & Singh, J. (2022). Artificial intelligence in transportation industry. *International Journal of Innovative Science and Research Technology, 7*, 1274–1283.

Patarroyo, D. J. R., Garzón, I. F. C., & Forero, C. A. L. (2019). Revision of smart street lighting LED. *Ingeniería Solidaria, 15*(2), 1–28. https://doi.org/10.16925/2357-6014.2019.02.09

Pattanaik, V., Singh, M., Gupta, P. K., & Singh, S. K. (2016, November). Smart real-time traffic congestion estimation and clustering technique for urban vehicular roads. In *2016 IEEE region 10 conference (TENCON)* (pp. 3420–3423). IEEE.

PwC. (2016). *Blockchain - An opportunity for energy producers and consumers*. PwC global power and utilities.

Quan, S. J., Park, J., Economou, A., & Lee, S. (2019). Artificial intelligence-aided design: Smart design for sustainable city development. *Environment and Planning B: Urban Analytics and City Science, 46*(8), 1581–1599.

Reyna, A., Martín, C., Chen, J., Soler, E., & Díaz, M. (2018). On blockchain and its integration with IoT. Challenges and opportunities. *Future Generation Computer Systems, 88*, 173–190.

Samsung, S. (2023). *Brightics AI*. Samsung SDS. Retrieved June 23 from https://www.brightics.ai/.

Samsurijan, M. S., Ebekozien, A., Nor Azazi, N. A., Shaed, M. M., & Radin Badaruddin, R. F. (2022). Artificial intelligence in urban services in Malaysia: A review. *PSU Research Review, 1-20*. https://doi.org/10.1108/PRR-07-2021-0034

Sanchez, T. W., Shumway, H., Gordner, T., & Lim, T. (2023). The prospects of artificial intelligence in urban planning. *International Journal of Urban Sciences, 27*(2), 179–194. https://doi.org/10.1080/12265934.2022.2102538

Saner, R., Yiu, L., & Nguyen, M. (2020). Monitoring the SDGs: Digital and social technologies to ensure citizen participation, inclusiveness and transparency. *Development and Policy Review, 38*, 483–500. https://doi.org/10.1111/dpr.12433

Schintler, L. A., & McNeely, C. L. (2022). Artificial intelligence, institutions, and resilience: Prospects and provocations for cities. *Journal of Urban Management, 11*(2), 256–268.

Sharifi, A., Allam, Z., Bibri, S. E., & Khavarian-Garmsir, A. R. (2024). Smart cities and sustainable development goals (SDGs): A systematic literature review of co-benefits and trade-offs. *Cities, 146*, Article 104659.

Shift. (2022). Using AI to monitor mobility modes across the park. https://shiftlondon.co.uk/discover/using-ai-to-monitor-mobility-modes-across-the-park/. (Accessed 7 December 2023).

Singh, A., Kanaujia, A., Singh, V. K., & Vinuesa, R. (2023). Artificial intelligence for Sustainable Development Goals: Bibliometric patterns and concept evolution trajectories. *Sustainable Development, 1-31*. https://doi.org/10.1002/sd.2706

Sirmacek, B., Gupta, S., Mallor, F., Azizpour, H., Ban, Y., Eivazi, H., … Vinuesa, R. (2023). The potential of artificial intelligence for achieving healthy and sustainable societies. In F. Mazzi, & L. Floridi (Eds.), *The ethics of artificial intelligence for the sustainable development goals* (pp. 65–96). Cham: Springer. https://doi.org/10.1007/978-3-031-21147-8_5.

Skouby, K. E., Kivimäki, A., Haukiputo, L., Lynggaard, P., & Windekilde, I. M. (2014, May). Smart cities and the ageing population. In *The 32nd meeting of WWRF* (pp. 1–12).

SmartCitiesWorld. (2023). AI used to monitor and optimise Swedish road infrastructure. https://www.smartcitiesworld.net/ai-and-machine-learning/ai-and-machine-learning/ai-used-to-monitor-and-optimise-swedish-road-infrastructure. (Accessed 7 December 2023).

Soberman, R. M. (1997). Rethinking urban transportation: Lessons from Toronto. *Transportation Research Record, 1606*(1), 33–39.

Stathis, M., Marc, B., Nora, B., Tom, L., Anthony, S., Andrea, P., & Gabriele, F. (2022, Sep 12-15). Challenges from the introduction of artificial intelligence in the European air traffic management system. In *15th IFAC/IFIP/IFORS/IEA symposium on analysis, design and evaluation of human-machine systems (HMS), San Jose, CA*. https://doi.org/10.1016/j.ifacol.2022.09.440

Suseendran, S. C., Nanda, K. B., Andrew, J., & Bennet Praba, M. S. (2018). Smart Street lighting System. In *3rd International Conference on Communication and Electronics Systems (ICCES)* (pp. 630–633). India: Coimbatore. https://doi.org/10.1109/CESYS.2018.8723949.

Teh, D., & Rana, T. (2023). The use of internet of things, big data analytics and artificial intelligence for attaining UN's SDGs. In T. Rana, J. Svanberg, P. Öhman, & A. Lowe (Eds.), *Handbook of big data and analytics in accounting and auditing* (pp. 235–253). Singapore: Springer Nature Singapore. https://doi.org/10.1007/978-981-19-4460-4_11.

Ullah, Z., Al-Turjman, F., Mostarda, L., & Gagliardi, R. (2020). Applications of artificial intelligence and machine learning in smart cities. *Computer Communications, 154*, 313–323.

UN Department of Economic and Social Affairs. (2018). 2018 world urbanization prospects [WWW document]. URL https://population.un.org/wup/. (Accessed 23 March 2023).

UN-Habitat. (2022). World cities report 2022: Envisaging the future of cities [WWW document]. URL https://unhabitat.org/wcr/. (Accessed 13 July 2023).

United Nations Department of Economic and Social Affairs, Population Division. (2022). *World population prospects 2022: Summary of results*. UN DESA/POP/2022/TR/NO. 3.

United Nations General Assembly. (2015). Transforming our world: The 2030 agenda for sustainable development [WWW document]. URL https://sdgs.un.org/2030agenda. (Accessed 8 December 2021).

Vijayakumar, K., Wylie, S. R., Cullen, J. D., Wright, C. C., & Ai-Shamma'a, A. I. (2009, July). Non invasive rail track detection system using microwave sensor. In *, Vol. 178, No. 1. Journal of physics: conference series* (p. 012033). IOP Publishing.

Vinuesa, R., Azizpour, H., Leite, I., Balaam, M., Dignum, V., Domisch, S., … Fuso Nerini, F. (2020). The role of artificial intelligence in achieving the Sustainable Development Goals. *Nature Communications, 11*(1), 233. https://doi.org/10.1038/s41467-019-14108-y

Voto, A. (2017). Blockchains and the civic nervous system. Field actions science reports. *The Journal of Field Actions*, (Special Issue 17), 60–63.

Ward-Foxton, S. (2021). Smart city AI trial in Rome could help you find a parking space. https://www.eetimes.eu/smart-city-ai-trial-in-rome-could-help-you-find-a-parking-space. (Accessed 7 December 2023).

Wen, J., Okolo, C. V., Ugwuoke, I. C., & Kolani, K. (2022). Research on influencing factors of renewable energy, energy efficiency, on technological innovation. Does trade, investment and human capital development matter? *Energy Policy, 160*, Article 112718.

Winner, L. (1978). *Autonomous technology: Technics-out-of-control as a theme in political thought*. USA: MIT Press.

Wirtz, B. W., Weyerer, J. C., & Geyer, C. (2019). Artificial intelligence and the public sector—Applications and challenges. *International Journal of Public Administration, 42*(7), 596–615.

Yezioro, A., Dong, B., & Leite, F. (2008). An applied artificial intelligence approach towards assessing building performance simulation tools. *Energy and Buildings, 40*(4), 612–620.

Yigitcanlar, T., Corchado, J. M., Mehmood, R., Li, R. Y. M., Mossberger, K., & Desouza, K. (2021). Responsible urban innovation with local government artificial intelligence (AI): A conceptual framework and research agenda. *Journal of Open Innovation: Technology, Market, and Complexity, 7*(1), 71.

Yigitcanlar, T., & Cugurullo, F. (2020). The sustainability of artificial intelligence: An urbanistic viewpoint from the lens of smart and sustainable cities. *Sustainability, 12*(20), 8548. https://doi.org/10.3390/su12208548

Yigitcanlar, T., Kankanamge, N., Regona, M., Ruiz Maldonado, A., Rowan, B., Ryu, A., … Li, R. Y. M. (2020). Artificial intelligence technologies and related urban planning and development concepts: How are they perceived and utilized in Australia? *Journal of Open Innovation: Technology, Market, and Complexity, 6*(4), 1–21. https://doi.org/10.3390/joitmc6040187

Yin, M., Li, K., & Cheng, X. (2020). A review on artificial intelligence in high-speed rail. *Transportation Safety and Environment, 2*(4), 247–259.

Yin, R. K. (2017). *Case study research and applications: Design and methods* (6 ed.). SAGE Publications https://us.sagepub.com/en-us/nam/case-study-research-and-applications/book250150.

Younes, M. K., Sulaiman, G., & Al-Mashni, A. (2020). Integration of traffic management and an artificial intelligence to evaluate urban air quality [article]. *Asian Journal of Atmospheric Environment, 14*(3), 225–235. https://doi.org/10.5572/ajae.2020.14.3.225

Zang, Y., Shangguan, W., Cai, B., Wang, H., & Pecht, M. G. (2019). Methods for fault diagnosis of high-speed railways: A review. *Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability, 233*(5), 908–922.

Zantalis, F., Koulouras, G., Karabetsos, S., & Kandris, D. (2019). A review of machine learning and IoT in smart transportation. *Future Internet, 11*(4), 94.

Zhang, Y. (2017). *CityMatrix: An urban decision support system augmented by artificial intelligence*. Doctoral dissertation. Massachusetts Institute of Technology.

Zhao, N., Zhang, H., Yang, X., Yan, J., & You, F. (2023). Emerging information and communication technologies for smart energy systems and renewable transition. *Advances in Applied Energy, 9*, Article 100125. https://doi.org/10.1016/j.adapen.2023.100125

Zhao, W., Yin, C., Hua, T., Meadows, M. E., Li, Y., Liu, Y., Cherubini, F., Pereira, P., & Fu, B. (2022). Achieving the Sustainable Development Goals in the post-pandemic era. *Humanities and Social Sciences Communications, 9*, 258. https://doi.org/10.1057/s41599-022-01283-5