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Integration of new age technology with smart cities initiatives and its role in the achievement of sustainable development goals

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Abstract

The United Nations General Assembly set up 17 goals to achieve environmental, socioeconomic, and industrial infrastructure challenges, practically framed within 169 targets and 232 indicators. In this view, the Smart Cities initiative is assumed to be a hotspot for achieving the United Nations goals by 2030, aligned with Sustainable Development Goals 8, 9, and 11. This study explores the role of Smart Cities initiatives in achieving Sustainable Development Goals 8, 9, and 11. A structured literature review was utilized to perform a content analysis of existing studies, practically focusing on identifying and understanding the capabilities of Smart Cities initiatives in achieving Sustainable Development Goals 8, 9, and 11. The findings covered the environmental, socioeconomic, and infrastructure-based factors of the Smart Cities framework as supported by the achievement of the aforementioned Sustainable Development Goals. The synergies between technological innovation, urban development, and sustainability of Smart Cities provide strategic guidelines for policymakers, social and industrial entrepreneurs, and managers, and inform future research directions for academic researchers.

Keywords: Smart cities, Sustainable Development Goals, United Nations, Environmental, Socioeconomic, Industrial infrastructure

1. Introduction

In 2015, with the aim of achieving peace, prosperity, and environmental sustainability for future generations, the United Nations (UN) adopted the 2030 Agenda for Sustainable Development as a global framework. It launched 17 Sustainable Development Goals (SDGs), accompanied by 169 targets and 232 indicators, as a response to tackle the root causes of environmental, socio-economic, and industrial infrastructure challenges. These goals have been implemented through policy advisory, knowledge sharing, research and development, and innovative capacity development, emphasizing collaborations with Least Developed Countries (LDCs) [1]. To achieve these SDGs, world leaders at the UN Office for Sustainable Development (UNOSD) forum focused on creating sustainable urban areas and cities in LDCs by planning and implementing innovative technologies.

Initially, the notion of SDGs was derived in 1987 from the "Gro Harlem Brundtland Commission" report entitled "Our Common Future," formally known as the "World Commission on Environment and Development" (WCED) [2]. The report aimed to unite global leaders to prioritize long-term solutions for environmental protection, economic development, and social equity by promoting urban sustainability. As an extension of the Brundtland Commission, the SDGs incorporate modern city patterns and implement policies and plans to address key urbanization issues, including industrial infrastructure, education, health, poverty, gender discrimination, climate action, access to clean water, and sustainable economic growth [3-4]. According to the World Bank estimates, over 56% (4.4 billion) of the world population currently lives in cities, and this is projected to increase from 68% to 70% by 2050 [5].

In this regard, prior studies on the achievement of SDGs have argued that innovative technological frameworks, such as human-centered ones, play an essential role in balancing socio-economic and environmental challenges by integrating with Smart Cities initiatives [6-8]. Likewise, Kuzior [9] pointed out that the Smart Cities initiatives were formulated by integrating artificial intelligence (AI), the Internet of Things (IoT), Cyber-Physical Systems (CPS), and Big Data Analytics (BDA) into a unified ecosystem of cities. In this view, Parra-Domínguez et al. [10] outlined that the Smart Cities initiatives significantly contribute to achieving SDGs by implementing innovative technologies and data-driven decision-making strategies for societies and industries.

Similarly, an empirical study by Kasinathan et al. [11] explored the potential role of Smart Cities in pursuing SDGs. It concluded that Smart Cities play a significant role in achieving the SDGs. However, due to the novelty of smart cities in academia, there have been limited studies that have examined their role in the achievement of SDGs [12]. Although there is a limited empirical study that has critically analyzed and acknowledged the role of Smart Cities in the achievement of SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 11 (Sustainable Cities and Communities) specifically.

Noticeably, the SDG Resource Centre reported that the limited studies address the solutions to achieve SDG 8, SDG 9, and SDG 11 (SDG Resource Centre 2024). Thus, Figure 1 illustrates the number of published papers that examined the achievement of the 17 SDGs between 1 July 2024 and 5 August 2024, which is evidence that there is a scarcity of studies that investigate the strategic framework required to achieve SDG 8, SDG 9, and SDG 11. Subsequently, no existing studies have proposed a strategic framework to explore the role of Smart Cities in achieving SDGs 8, 9, and 11 specifically.

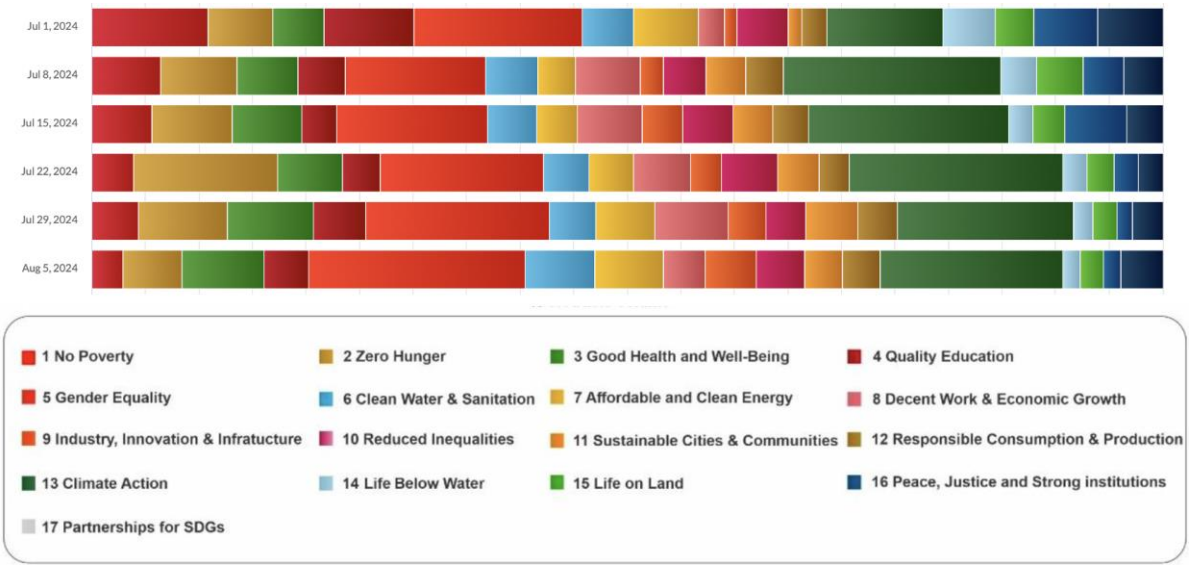

Figure 1. Recently published studies on each SDG; Source: SDG Resource Center [13]

Demonstrating the existing challenges in achieving SDGs, the International Labor Organization (ILO) warns that the global unemployment rate is projected to rise by 5.1% to 5.2% in 2024 [14]. The job gap rate in high-income countries is 8.2%; in low-income countries, it is significantly higher at 20.5% [14]. In addition, the

Purchasing power parity (PPP) per person per day is estimated at USD 2.15 for workers living in extreme poverty and USD 3.65 for workers living in the moderate poverty line [14]. This data highlights the urgent need for targeted interventions to address poverty, inequality, and unemployment, which define the agendas of SDG 8 and align with the novel concept of Smart Cities initiatives. According to a recent report by the SDGs Index UN [15], no country has fully achieved SDG8, highlighting significant and major challenges in its practical implementation (see Appendix A).

A recent thematic review by the UN on SDG 9 also highlighted that the COVID-19 pandemic and geopolitical tensions had pushed the global economy into a recession. As a result, a significant lack of investment in research and development, innovations, and infrastructure within the manufacturing sector, particularly in most LDCs [1]. Furthermore, insufficient prioritization of policies, limited access to resources, and the low productivity of micro, small, and medium-sized enterprises (MSMEs) during the COVID-19 pandemic have posed severe challenges to inclusive industrialization. The year 2022 also marked a critical turning point as global CO2 emissions saw a 0.9% increase, a record high of 36.8 billion metric tons [1]. Empirically, Kuzior [9] suggested that the Smart Cities initiatives empower innovative industrialization by utilizing Industry 4.0 paradigms, which significantly support the achievement of SDG 9. Thus, only three countries worldwide (i.e., the United Kingdom, Singapore, and Japan) have successfully achieved SDG9 [15], while these countries ranked 6, 7, and 72 in the Smart City index (see Appendix A). This indicates significant challenges for other countries in implementing strategic policies to achieve this goal.

Third, a special report on SDG 11 by the UN revealed that over 55% of the world's population lives in urban areas, which is projected to rise by over 70% by 2050. From this urban population, 1.1 billion people are living in unsafe, unhealthy, overcrowded, and undesirable settlements, intensifying urban poverty and inequalities, and this number is expected to increase to 2 billion by 2050 [15]. Half of this urban population has insufficient access to primary education, healthcare, efficient public transportation, and affordable housing schemes. Therefore, out of 193 UN member countries and independent states, only Germany has achieved SDG 11 [15], which ranked 11th in the Smart City Index [45], indicating that major and significant challenges remain for other countries (see Appendix A).

However, one of the main challenges is the implementation of Smart City technologies, which often result in a digital divide that intensifies existing social and economic inequalities, stakeholder engagement, and knowledge and capabilities within the context of SDGs [6-7]. For these reasons, this study aims to perform a "Structured Literature Review" (SLR) [16] to explore (1) a comprehensive understanding of how Smart Cities support the achievement of SDGs 8, 9, and 11; and (2) identify critical research avenues for future research studies. Thus, the present study sheds light on the Smart Cities drivers by identifying and proposing new system-based plans and policy implementations that address social and economic inequalities, stakeholder engagement, and knowledge and capabilities plans and policies to effectively attain SDGs 8, 9, and 11.

2. Smart cities initiatives

In the 1990s, the term Smart City began to appear in academic and industry discussions, primarily focused on integrating information and communication technologies (ICT) in urban infrastructure [17]. The term was widely recognized and discussed in the mid-2000s [18] when cities began installing and experimenting with innovative technologies, including sensor networks, data analytics, AI, IoT, and mobile applications [19]. These technologies were employed to enhance the quality of life for citizens by leveraging ICT in urban infrastructure to optimize the management of resources, services, and infrastructure systems [20]. In addition, Sharifi et al. [19] noted that the emerging concept of Smart Cities was initially shaped by utilizing ICT in urban planning, development, and sustainability to enhance smart connectivity and IoT infrastructure, smart resilience and safety, smart mobility and transportation, smart education, and smart living.

Scuotto et al. [21] have stated that the early Smart City concept called "Smart Plane," which was launched in 2025 by IBM, focused on planning and developing "Wired Cities." This initiative utilized broadband internet

and sensor technology to enhance city services, including health, transportation, public safety, education, and waste management. Likewise, in 2010, the European Union (EU) launched the Smart Cities and Communities project, aimed at encouraging countries across Europe to initiate innovative urban projects that integrate ICT, transportation systems, and energy consumption at individual and organizational levels [22-23]. Similarly, following the UN Smart Cities' mission, South Korea initiated the Songdo International Business District in the 2000s, and in 2006, Masdar City was developed by the United Arab Emirates (UAE) [24].

Overall, existing studies on Smart Cities reported that they significantly reduced ecological footprint through the implementation of intelligent systems, such as smart grids, waste management, and energy-efficient buildings [25-27]. Such practices align with SDGs 8, 9, and 11 related to decent work and economic growth, climate action, affordable and clean energy, and sustainable cities and communities [28].

3. Research method

Provide sufficient detail to allow the work to be reproduced. Methods already published should be indicated by a reference; only relevant modifications should be described. To explore and understand the critical role of Smart City initiatives in achieving SDG 8, 9, and 11, we applied the Structured Literature Review (SLR) technique. According to Troisi et al. [16], SLR is considered a robust method for conducting critical analysis, identifying key trends, and mapping research directions for future studies across various fields. Therefore, the SLR approach has been applied by prior studies in areas such as intellectual capital [29-30], supply chain transparency [31], and circular economy and SDGs [32]; thus, limited studies applied SLR techniques to examine the role of Smart Cities in the achievement of SDGs. Existing studies have not yet explored the diverse impacts of Smart Cities on achieving SDGs. Thus, most academicians and practitioners are unaware of the different conceptual issues involved.

In this regard, SLR is a dominant approach that offers an in-depth understanding of previously unidentified concepts and analyzes the fundamental frameworks that define the integrated paradigm of smart cities by critically investigating their role in achieving specific SDGs. However, the research design for the present study was formulated based on the six phases of SLR [33], and the research protocol [16] presented in Figure 2 and elaborated in the following subsections.

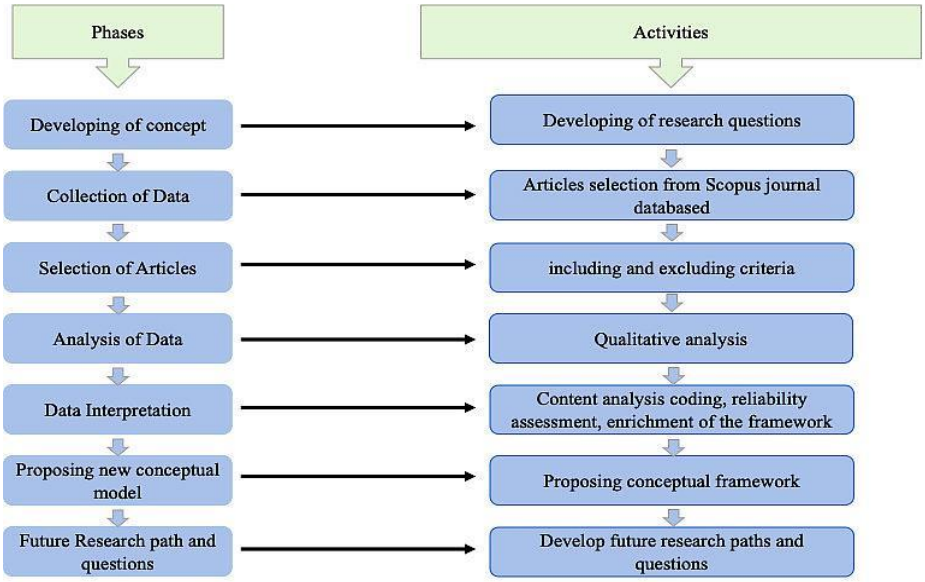

Figure 2. Phases of the SLRs in research design

3.1. Step 1: Conceptualization and definition of research questions

In this first phase, research questions were developed based on the rationale for SLR, emphasizing the urgent need to examine key concepts that previous studies have not explored. The present study aimed to assess and

map the conceptualization of Smart Cities to achieve SDGs 8, 9, and 11 and identify future research needs by implementing a critical approach for academia. Existing scholarly work utilizing the SLR approach suggests that critical studies should address three broader aims: (1) Insights: Examining the phenomenon that defines the key issues within the conceptualized model; (2) Critique: Analyzing the relationship between key concepts and/or constructs, such as the role of Smart Cities in achieving SDGs; (3) Transformative redefinition: Synthesizing findings from previous studies to reframe the existing conceptualizations and formulate a new conceptual framework [16].

Therefore, based on the research gaps identified by the existing literature, the following research questions for the present study were proposed:

- RQ1. How do Smart Cities initiatives play an important role in achieving SDGs 8, 9, and 11?
- RQ2. What are the key future developments and main implications for research on Smart Cities and SDGs?

Based on the three research questions above, different codes and classifications were identified to establish filters and parameters for selecting the most relevant articles from a reputable, peer-reviewed literature database.

3.2. Step 2: Data collection and sampling

Scholarly journals were identified using the Scopus database powered by Elsevier. The search string "Smart cities" OR "Smart city" AND "Sustainable development goals" OR "SDGs" was used to explore titles, abstracts, and keywords. The search focused on peer-reviewed articles published in English from 2010 to 2023, resulting in 60 articles found. Conferences and book chapters were excluded to ensure more accuracy in the research findings [29].

Before article selection, after reviewing the titles, abstracts, and keywords, overall 60 articles were selected; 37 were excluded (including 19 not accessible articles, seven conference papers, six books, and five book chapters), resulting in a final sample of 23 papers. Scopus was adopted as the primary database because it included most of the scholarly work indexed in Web of Science (WoS) and Emerald [16]. Therefore, ten articles were excluded in the second phase due to irrelevance, leaving 13 articles discussing Smart Cities and SDGs for the systematic review. Subsequently, the third phase involved analyzing the co-occurrence of keywords and contributions in line with methodologies employed in earlier studies [11], [34]. Finally, in the fourth phase, the results from the systematic review were presented and discussed. A comparative analysis was conducted to examine Smart Cities and SDGs and to understand the differences in categories, such as the specific characteristics of Smart Cities that contribute to achieving SDGs 8, 9, and 11 precisely.

3.3. Step 3: Criteria for article selection

In the third phase, the following exclusion criteria were applied: (a) articles that did not focus on Smart Cities and SDGs together; (b) conferences, proceedings, and/or book chapter reviews; (c) non-English language articles; and (d) articles with incomplete texts. A final sample of 20 articles were obtained. To determine the relevance of the research to the research questions, the analytical framework was based on the following criteria: (a) focus of study, (b) methodology, (c) key findings, (d) contributions, and (e) potential avenues for future research.

3.4. Step 4: Data analysis with coding, reliability assessment, enrichment of the framework

The fourth phase of this SLR involved a comprehensive analysis of the selected articles using descriptive analysis and a coding process to map the development of the study field, identify the current trends, and evaluate the influence of relevant constructs for each research question. During the assessment, a descriptive analysis, frequency distribution (by year), and charts (by subject area) were created to capture bibliographic information on existing literature and its progress and outline the associations and themes defining the key constructs. Hence, the papers were categorized by author, country, title, finding, contribution, research gap, and future research recommendation. This classification was conducted to identify the most relevant studies and codes and align

them with the research questions. Ultimately, developing a new conceptual framework and providing recommendations for future research directions.

The content analysis and coding process enabled the study to identify common research areas and characteristics. A flexible coding approach was employed to allow for the iterative emergence of new categories during the analysis. As illustrated in Figure 3, previously unidentified factors are based on insights from the obtained data.

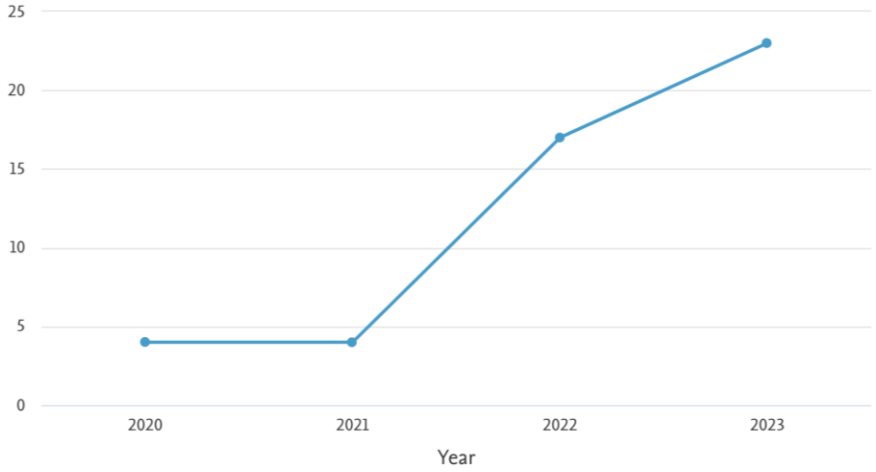

Figure 3. Article publications from 2010 to 2023

3.5. Step 5: Data interpretation and discussion of results

In phase 5, a concept-centric approach was employed to conceptualize broader issues, which encompassed analyzing each fundamental construct, classifying new factors, and developing a new conceptual framework. According to Troisi et al. [16], sense-making is used as an interpretative technique within a "hermeneutic paradigm" that (1) classifies key constructs for each research question using a deduction approach and (2) reorganizes empirical data collected during the analysis process (induction) to formulate a new conceptual framework by highlighting relationships between constructs and/or dimensions. Further, Troisi et al. [16] observed, "Critical skills have been applied through an open-minded approach that leads researchers, starting from the possession of some guidelines, beliefs and personal knowledge, to develop the ability to manage large sets of data and to be constructive to extract new connections between existing elements, new ideas and reveal new concepts to be explored" (p.29). Overall, the findings support the formulation of a new conceptual framework that identifies the key outcomes and the role of Smart Cities in achieving SDGs 8, 9, and 11. This framework highlights the importance of future research and the key strategic drivers to implement and achieve the SDGs.

3.6. Step 6: Theory contribution and development of future research directions

The last phase is grounded in developing theoretical and practical knowledge related to Smart Cities and SDGs and developing managerial implications to provide the necessary skills to outline new approaches for government agencies, policymakers, and other stakeholders. Research gaps can be highlighted by elaborating on less explored areas, encouraging future research to identify current issues, trends, and new research avenues. This study recommends adopting novel or integrated approaches by identifying prevalent research methodologies. This guidance can inform future research by justifying specific methods, theories, and conceptual frameworks.

4. Findings

The final sample of 20 papers underwent a preliminary descriptive analysis based on the key areas and article characteristics. Subsequently, these papers were subject to a rigorous content analysis of the texts. The findings are detailed in the following sub-sections.

4.1. Descriptive analysis

The descriptive analysis of the study categorized the papers based on total paper publications per year, research fields, total citations, and common keywords, which were then analyzed using a content analysis approach. Figure 4 indicates the classification of the papers from 2010 to 2023. The overall analysis reveals a gradual and constant progress, which concluded in 2023 and confirms the progressive expansion of the identified theme, particularly following the initiation of the disruptive analysis process. Therefore, Figure 4 presents different fields of published articles discussing Smart Cities and SDGs from 2010 to 2023.

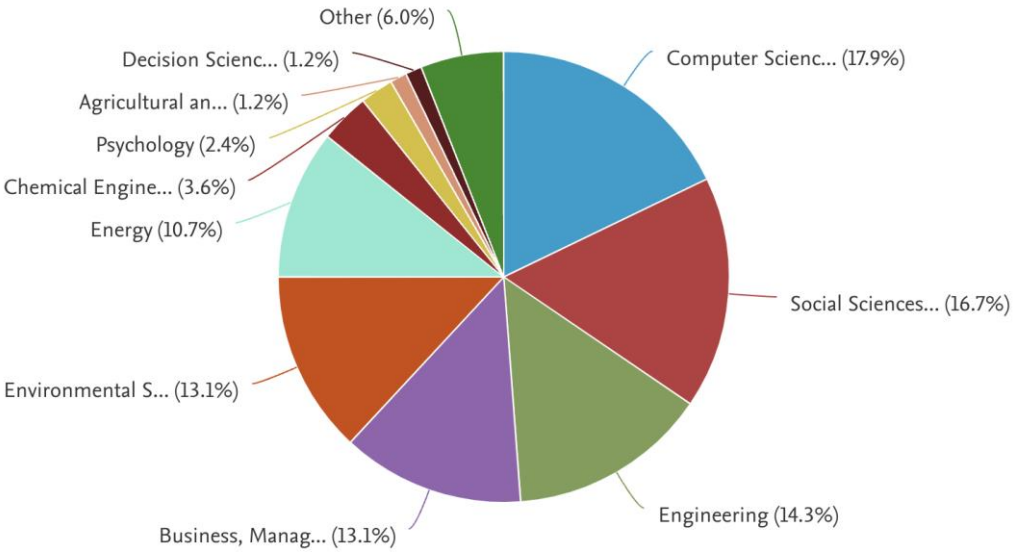

Figure 4. Field of previous studies from 2010 to 2023

4.2. SDG 8: Decent work and economic growth

The final sample of 20 papers underwent a preliminary descriptive analysis based on the key areas and article characteristics. Subsequently, these papers were subject to a rigorous content analysis of the texts. The findings are detailed in the following sub-sections.

The COVID-19 pandemic has severely disrupted the global economy, hindering growth, entrepreneurship, and job creation. It has also interrupted the production and supply chains, increasing vulnerabilities in the services and manufacturing sectors. Consequently, billions of lives worldwide were affected, jeopardizing the global economy and significantly hindering efforts toward achieving SDG 8. The situation was exacerbated by additional crises and geopolitical tensions, further impacting economic productivity, per capita income, gender equality in equal employment opportunities, and resource consumption and production (SDG 12). To achieve the targets of SDG 8 by 2030, several developed countries such as the USA, China, the UK, France, Italy, and Japan are adopting modern economic models that align with the Green Economy and Circular Economy [3], [32]. These financial models support strategic policy objectives and smart practices for sustainable economic growth while minimizing environmental impacts. As of September 2024, no country has achieved SDG 8.

For effective management of production and consumption of resources within the umbrella of SDG8, the circular economy necessitates advanced technical innovations to boost institutional capacities and reach the maximum level to enable evidence-based policy reforms, modernize infrastructure, and facilitate innovative financial mechanisms. Prior studies have reported that the circular economy is pivotal for achieving SDGs in Smart Cities [20], [35]. Compatible integration of green and digital economies fosters knowledge-based productivity and growth in infrastructure and manufacturing firms. Such integrations enhance innovative productivity and reduce risk mitigation while improving spatial accessibility challenges, allowing efficient resource management services for diverse communities [36]. They also offer opportunities to decouple economic growth from environmental degradation.

However, the COVID-19 pandemic has exposed enormous corporate greed and exacerbated wealth, widening the gap between the poor, middle class, ruling class, and privileged class in several democratic societies. It has undermined decent work and continues to challenge economic growth challenges and fair distribution of costs and wealth. Urgent action is required to address and overcome current crises, such as decent work and economic growth (SDG 8), which were affected by the COVID-19 pandemic. In this regard, designing and implementing a digitalized economy and balanced decent work environment within Smart Cities is a potential solution to this global crisis. On the other positive side, the COVID-19 pandemic accelerated e-commerce and digital transformation across nearly all economic sectors worldwide by reshaping consumer behavior. These changes in consumer behavior are a positive indicator of financial processes, government policies, and framework strategies, providing efficient data infrastructure for integrating digital platforms into urban economic sectors.

Overall, prior studies have confirmed that economic transformations are reshaping socio-technical imaginaries and cultural practices around digital platforms [37-38], particularly in the context of Smart Cities, which aligns with SDG 8 [6].

4.3. SDG 9: Industry, innovation and infrastructure

Smart Cities initiatives have a dynamic capacity to drive societal and industrial changes by collaborating with advanced technologies and innovative infrastructure tools [11]. The extensive revolutionary concept of Smart Cities, where machines and men work together, promises an unprecedented transformation in production efficiency [6]. As discussed earlier, the evolution of Society 1.0 to Society 5.0 has developed alongside the production and operations of the manufacturing industry, serving as the foundation of industrial progress from the "First Industrial Revolution" to the current era of "Digital Transformation." Hence, the importance of developing technologically innovative processes to bring sustainable change to the manufacturing industry is evident in SDG 9 [19]. The primary focus of Smart Cities is to create a human-centered society that utilizes advanced ICT and IoT systems to balance economic progress while addressing existing automation challenges and complex industrial and societal problems.

In this regard, Goel et al. [39] suggested that ICT and IoT are influential factors in advancing and protecting society, promoting socio-economic development, optimizing resource production and consumption, advancing infrastructure, and human-centered approaches in cities via automated and efficient concepts. Smart Cities adopt ICT and IoT-based technologies that offer cutting-edge solutions for optimizing the sustainability of production and consumption in urban areas. This includes improving urban governance, strategic designs, planning, operations, and implementation.

In addition, Smart Cities, through the integration of ICT, IoT, 5G network, BDA, and cloud computing, exemplify a shift in urbanization by addressing long-term, complex urban challenges such as resource production and consumption, safety, healthcare, and air pollution [40]. Further, this infrastructure underpins the functionality of Smart City services such as smart grids, intelligent transportation systems, and automated public services, enabling real-time decision-making, safety, and efficient resource management. These integrated solutions align with the key objectives of SDG 11, which include resilience, equity, inclusivity, safety, and quality of life. However, as Shahmohammad et al. [41] cautioned, optimization approaches can sometimes neglect environmental and social considerations and limit citizen participation in planning innovative urban projects.

Integrating resilient infrastructure in Smart Cities is critical for achieving the objectives of SDG 9. For instance, prior studies have suggested that advanced technologies such as data sensing and analytics, deep learning, Blockchain, drone-based sensing, and AI can automatically detect and respond to disruptions, ensuring a stable and reliable energy supply in Smart Cities, as evident in several cities such as Oslo, Norway [42-43]. Similarly, Sharifi et al. [19] stated that smart energy and water management systems utilize real-time data to monitor and optimize energy and water distribution, reducing waste and enhancing resource efficiency.

In addition, the synergy of Smart Cities enables advanced manufacturing technologies such as 3D urban environment models, AI, and robotic transformation to contribute to an enhanced understanding of urban industrial phenomena within the context of SDG 9. Advanced technologies of Smart Cities promote more sustainable and efficient manufacturing processes, helping to control and minimize environmental impact while creating new economic opportunities. For instance, Blasi et al. [28] emphasized that implementing additive manufacturing in Smart Cities allows local production, promotes the circular economy, minimizes transportation emissions, and optimizes smart transportation systems, which significantly supports the achievement of SDG 9.

However, smart industrial innovation, a cornerstone of Smart Cities, plays a crucial role in achieving SDG 9 by enhancing the efficiency and sustainability of urban industrialization. In the context of SDG 9, these systems integrate AI, IoT, and big data to optimize the technological revolution that could transform the current working patterns, lifestyles, and work-life balance. This transformation would be unprecedented in scope, scale, and complexity, marking new experiences for individuals.

Prior studies have identified a broad range of emerging technologies yet to be explored. For instance, while Industry 4.0 technologies generated USD 100 trillion, the automobile industry alone is expected to grow from USD 3.5 trillion in 2016 and is projected to reach USD 6.6 trillion by 2030. As supported by Blasi et al. [28], the growth percentage is expected to be 84% when disruptive technologies are introduced, such as electrification, shared mobility, and connectivity. Therefore, the manufacturing industry must be innovative and adopt new transforming technologies to achieve SDG 9 in Smart Cities by utilizing Industry 4.0 technologies.

According to Kasinathan et al. [11], leveraging technology to enhance innovation and product development could generate approximately USD 166 billion to USD 477 billion in new revenue. Additionally, smart and efficient research and development (R&D) could contribute a further USD8 billion to 25 billion. It is forecasted that connected innovations and products could generate USD34 billion to USD95 billion in additional industry revenue [11]. Hence, manufacturing firms must adopt digital technologies to develop new products and services, sustain their competitive advantage, and expand their market shares. This approach helps firms address inefficiencies, strategize effectively, and proactively manage risks. In the study conducted by Sharifi et al. [19], a set of various transformational technologies and how they interact with society using ICT were explored. This included IoT, AI, Machine Learning (ML), automation processes, chatbots, Augmented Reality (AR), advanced computing and robotics, agricultural machinery, Big Data mining, autonomous vehicles, and digital currency.

4.4. SDG 11: Sustainable cities and communities

Smart City initiatives are evident in an innovative approach to business operations and accelerated digitalization, driving societal changes. This concept is being developed in the field of modern technology through smart city initiatives. The primary focus is to enhance the well-being of citizens by encouraging the development of smart societies that operate on diverse and extensive implications. In this view, cities are potent societal transformation catalysts connecting technological innovations and sustainable development. Previous studies have demonstrated that post-humanization in urbanization and the rise of smart solutions are universal trends with the potential to reshape our lives radically. Hence, the importance of modernizing innovative solutions to address sustainable urban development challenges is evident in SDG 11.

Advanced ICT and IoT are instrumental in safeguarding the environment, optimizing resources, stimulating socio-economic growth, modernizing infrastructure, and expanding knowledge in urban settings. This includes numerous factors, including urban strategic planning and design, and their implications. For instance, Zengin et al. [6] emphasized that BDA offers immense potential. However, it is essential to acknowledge the tensions between accuracy and uncertainty, transparency and opacity, and objectivity and subjectivity in its applications. This highlights the importance of algorithmic accountability to ensure greater confidence and transparency.

According to Blasi et al. [28], the urban mobility sector is the main priority of SDG 11. For example, cryptocurrency-based transportation concepts, such as “FiarBike,” have been introduced to enhance shared

mobility [19]. These cryptocurrency-based platforms can also serve as financial conduits for maintaining and expanding shared mobility infrastructure. In addition, smartphone apps and other smart technologies have significantly promoted smart public transportation systems [43]. Therefore, Smart transportation solutions, such as bike and car-sharing programs, can reduce travel demand by promoting online shopping and automated delivery while ensuring the safety of cyclists and pedestrians with sensor technology. Automated transport solutions are another essential feature of Smart cities. When planned and implemented effectively, these innovations can improve urban-rural integration, strengthen city-hinterland connections, and drive regional prosperity. Well-managed automated transportation solutions can also increase the accessibility of the elderly, women, and children. Additionally, installing a smart traffic system can improve road safety and reduce environmental impacts by minimizing the number of vehicles on the roads and lowering CO2 emissions [28].

However, Jain et al. [44] noted that poor installation of transport automation could negatively impact the environment and increase traffic congestion and CO2 emissions. Similarly, other studies have argued that Autonomous Vehicles (AVs) could potentially exacerbate car and bike dependency, leading to increased vehicle miles traveled, adverse public health consequences, and higher emissions [28]. According to Sharifi et al. [19], integrating AVs with "Mobility as a Service" (MaaS) and strategic policies of public transport could alleviate these issues, ultimately promoting car sharing and enhancing urban governance. Blockchain-based platforms can modernize collaboration between citizens and urban authorities by reducing bureaucracy and enhancing trust through secure management of data collected by smart IoT tools. These smart platforms optimize interactions by accelerating speed, improving efficiency, and preventing corruption through robust traceability features. As such, urban authorities can effectively use blockchain to collect taxes and verify taxpayer information, thereby enhancing municipal revenue.

Jain et al. [44] argued that innovative technologies may negatively affect urban governance by emphasizing efficiency and data gathering over the well-being of distinct ecosystems and species. According to the present study, Smart Cities initiatives may cause challenges, including governance corporatization, disempowerment, social exclusion, algorithmic bias, techno-centricity and reductionism, privacy loss, dataveillance, cyber-security risks, and democratic backsliding. The COVID-19 pandemic and the widespread deployment of intrusive technologies exacerbated these challenges. Nevertheless, it can be concluded that SDG 11 can be achieved by integrating Industry 5.0 and Smart Cities. Policymakers, therefore, should prioritize transformative endeavors to develop safer, more resilient, and sustainable urban environments.

4.5. Integration of new age technology for achieving the SDG framework

The United Nations (UN) established the SDGs with a holistic perspective to promote humanity and the ecosystem in society. Essentially, SDGs aim to foster sustainable development of humans, economy, gender equality, resource management, technological innovation, land and water conservation, and environmental collaboration. From academic and industrial perspectives, achieving the UN's goals is complex and filled with unparalleled uncertainties. This includes the COVID-19 pandemic and climate change, which have slowed the process. A recent report by the SDG Resource Centre from 2024 highlighted that the previous studies had addressed most of the 17 SDGs; however, very few studies have investigated the role of Smart Cities in achieving SDG 8, SDG 9, and SDG 11.

However, this study provided a pathway for achieving SDG 8, SDG 9, and SDG 11 through implementing Smart Cities applications using a qualitative analysis approach, specifically SLR. It offers a systematic framework for policymakers and researchers by highlighting the potential to navigate data-driven, technology-defined pathways to achieve the SDGs by 2030. Due to the novelty of disruptive technologies, it has far-reaching implications for achieving the SDGs in the context of Smart Cities. Therefore, this study identified and presented the core infrastructure characteristics of Smart Cities initiatives in Figure 5, emphasizing the integration of technology to create urban environments that are sustainable, efficient, and conducive to the well-being of their residents, ultimately supporting the achievement of SDGs.

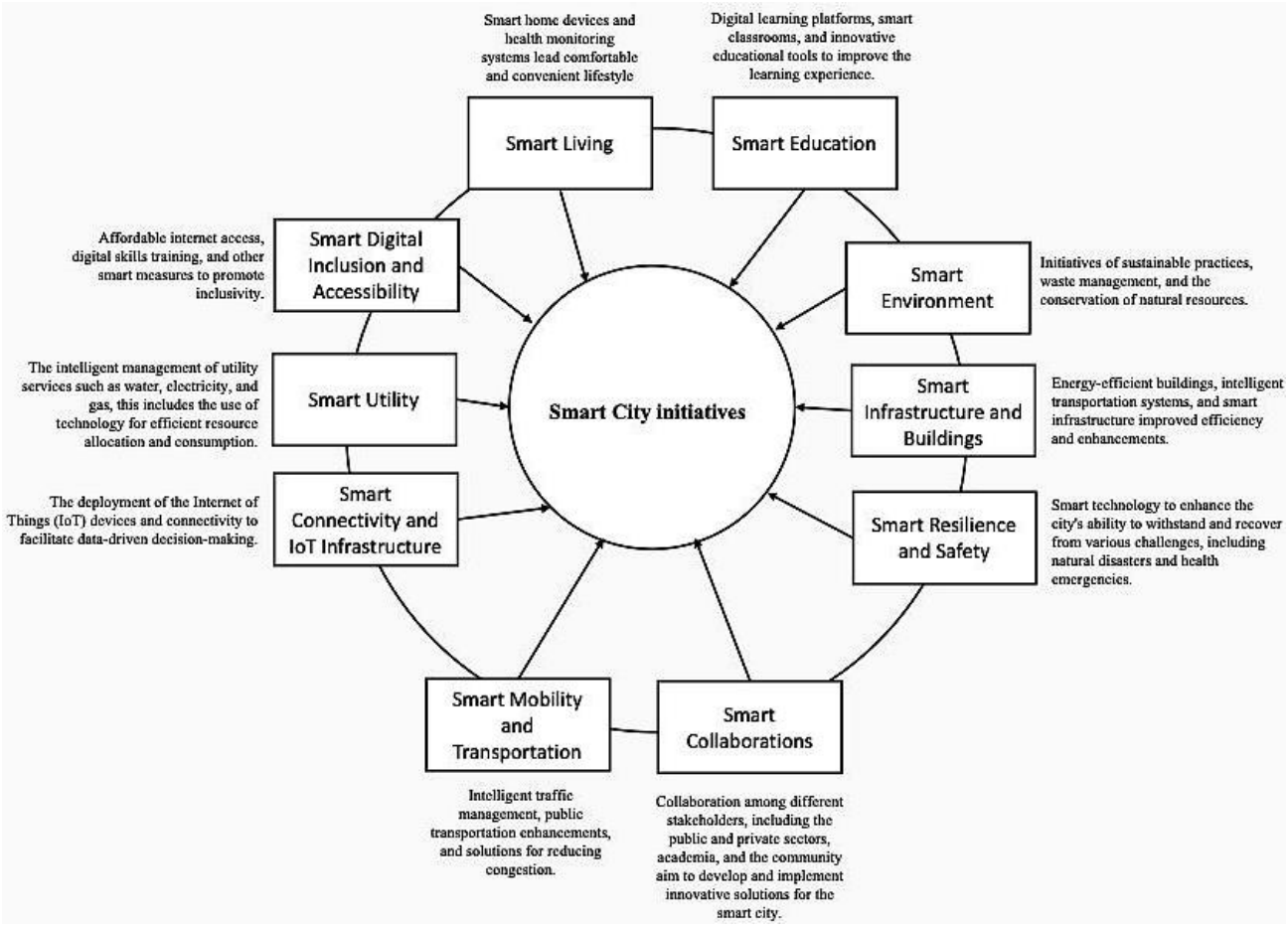

Figure 5. Core infrastructure characteristics of a smart city; Source: The authors (2024)

However, the present study proposed a conceptual framework mapping the disruptive technologies powered by Smart Cities towards achieving SDG 8, 9, and 11. Disruptive technologies have significantly impacted three SDGs, namely, SDG 8, SDG 9, and SDG 11, which have received less attention in previous studies. These three SDGs are crucial within the SDG framework since they foster potential progress for other SDG collaborations. This study has identified that disruptive technologies significantly impact SDG 9, given their role in improving the optimization and efficiency of infrastructure and smart manufacturing systems.

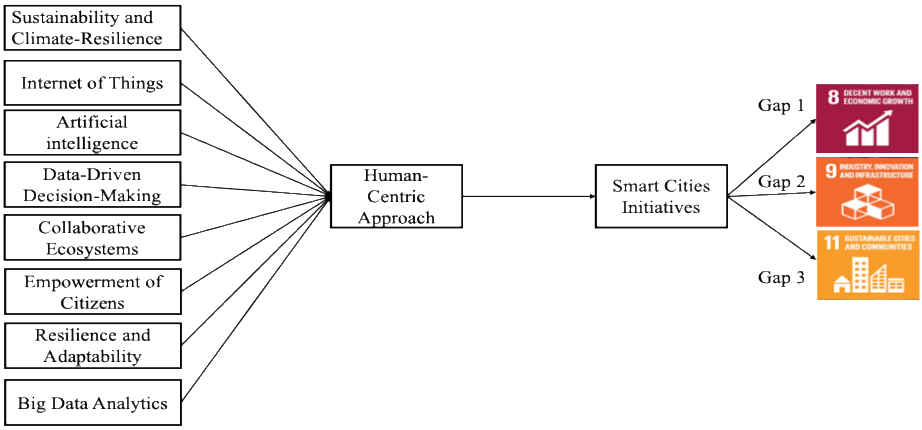

Figure 6. Proposed conceptual framework for future research; Demonstrated by authors (2024)

A conceptual framework, inclusive of data privacy and cybersecurity to guide future researchers, policymakers, and practitioners, was developed in this study and is presented in Figure 6. By addressing existing gaps and limitations, future research can contribute to the evolution of smart cities, ensuring that they not only harness technological innovations but also foster inclusivity, sustainability, and resilience in the face of dynamic societal

challenges. A phased implementation, progressing from industrial applications to societal integration, is essential for successfully adopting Smart Cities, which ultimately contribute to the achievement of SDGs. This approach allows for technological maturation and widespread adoption and ultimately leads to the emergence of more disruptive innovations.

Therefore, the present study proposes a conceptual framework (Figure 6) and a list of research questions (Table 1) for future studies that need to be critically explored.

From a future research perspective, the diagram highlights an essential framework for examining how Smart Cities initiatives can drive progress toward Sustainable Development Goals (SDGs) 8, 9, and 11. Future studies should delve deeper into the causal relationships between specific smart technologies (e.g., IoT, AI, big data analytics) and key performance indicators of each SDG. For example, how do AI-driven transportation systems impact employment patterns (SDG 8), or how does urban IoT infrastructure improve industrial efficiency and resilience (SDG 9)? Mixed-methods research could be employed, combining qualitative interviews with city planners and policymakers with quantitative analysis of urban performance metrics. Cross-country comparative studies would also be valuable to explore variations in Smart City effectiveness based on governance models and economic maturity. Furthermore, future work should investigate the role of citizen engagement and digital inclusion in ensuring that the benefits of smart innovations contribute equitably to sustainable urban development (SDG 11).

Table 1. Proposed research questions for future research

SDGs	Emerging questions for research
SDG 8	How can income inequality be reduced to promote sustainable economic growth in smart cities?
	What are the critical roles of balancing AI-driven and automation efficiency to create more employment?
	How do digital nomadism and remote working practices driven by Industry 4.0 support economic structures in Smart cities?
SDG 9	How does innovative infrastructure support sustainable industrial growth within Smart Cities initiatives?
	How do AI and IoT technologies in Smart cities enhance the sustainability and resilience of the manufacturing industry?
	How do 5G, blockchain, and quantum computing technologies foster innovation and industrial development in Smart cities?
SDG 11	How can Industry 5.0 be integrated into urban environmental planning to enhance resilience and sustainability in Smart cities?
	How do ICT and IoT technologies ensure social equity by addressing climate change and environmental sustainability?
	What role can citizen engagement and participatory governance play in shaping the development of smart cities in line with Society 5.0?

5. Discussion

This study uses the SLR research approach to explore the role of Smart Cities Initiatives in achieving SDG 8, 9, and 11. The findings have revealed positive and negative effects, prominently influencing SDGs 8, 9, and 11. The positive impacts stem from Society 5.0, particularly in healthcare, disaster management, and economic models, and the transition from Industry 4.0 to Industry 5.0. The study underscores the critical role of disruptive technologies in reshaping industry and society. A transformative framework of smart cities has addressed global challenges, fostered economic growth, and promoted social and environmental sustainability, as outlined in the SDGs [6, 28]. Integrating these paradigms represents a collective effort towards creating a more inclusive,

resilient, and sustainable world. Integrating Smart Cities within an eco-innovation framework is imperative for achieving environmental performance aligned with SDGs 7, 8, and 9. As digital technology advances rapidly, the transition to Industry 5.0 is inevitable. Industry 5.0 enhances data collection, analysis, and application, making operations more efficient, flexible, and cost-effective. In addition, both Smart Cities initiatives prioritize responsible consumption by implementing processes that foster craftsmanship and creativity, mainly adopting a circular economy in alignment with SDG 8, which is essential for tackling environmental priorities.

Smart city technology facilitates city operations and citizen services by integrating ICT and IoT networks. On the other hand, smart villages have introduced next-generation technology to rural areas, which can forecast risks, challenges, and opportunities for the well-being of people in both rural and urban settings. Empirical studies have delved into the advantages of the BDA paradigm for Smart Cities, emphasizing the importance of using data responsibly. Furthermore, they explore ways to promote socio-economic sustainability in these environments, ensuring alignment with technology-centered SDG 8 and through their interactions.

Building on the implications of this study, it is evident that Smart Cities initiatives have the potential to reshape how societies respond to global challenges. As demonstrated in Table 2, the alignment between specific Sustainable Development Goals (SDGs) and Smart Cities efforts underscores the importance of technological innovation, inclusive governance, and long-term strategic planning. However, the successful implementation of Smart City solutions is contingent upon multi-stakeholder collaboration, where governments, private sectors, and civil society collectively work toward inclusive and resilient urban development. Moreover, the transition toward Industry 5.0 and Society 5.0 amplifies the human-centric dimension of technological advancement [46-47]. These paradigms emphasize not just automation and efficiency, but also social well-being, ethical innovation, and sustainability. Smart Cities, therefore, must move beyond infrastructure and data integration to prioritize education, equity, and environmental resilience. Governments play a central role in this transformation by facilitating access to digital tools, investing in public-private partnerships, and enacting supportive regulatory frameworks. By integrating technological progress with human development goals, Smart Cities can help bridge socio-economic divides, enhance quality of life, and strengthen social cohesion. This extended framework supports a holistic vision where urban innovation serves as a vehicle for achieving sustainable, equitable, and peaceful societies—core aspirations of the 2030 Agenda for Sustainable Development.

Table 2. Role of smart cities in the achievement of SDGs 8, 9, and 11

SDG No.	SDG title	Purpose	Role of Smart Cities
SDG 8	"Decent Work and Economic Growth"	Promote sustained, inclusive, sustainable economic growth, full and productive employment, and decent work.	The development of Smart Cities fosters economic growth by creating job opportunities in technology-related sectors. Innovative infrastructure projects generate employment, and innovation hubs contribute to economic development.
SDG 9	"Industry, Innovation, and Infrastructure"	Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation.	Smart Cities prioritize innovation and invest in advanced infrastructure, including IoT networks, smart transportation systems, and digital connectivity. These initiatives enhance overall industrialization, innovation, and infrastructure development.
SDG 11	"Sustainable Cities and Communities"	Make cities and human settlements inclusive, safe, resilient, and sustainable.	Smart Cities focus on creating sustainable urban environments through efficient transportation, waste management, and green infrastructure. Urban planning and development in smart cities prioritize environmental sustainability and improved quality of life.

Following a critical analysis and exploring the objectives of SDGs 8, 9, and 11, the specific SDGs impacted by Smart Cities' initiatives were identified and categorized. Firstly, Smart Cities enhance environmental sustainability by optimizing resource utilization. They deploy smart grids, efficient waste management systems, and sustainable transportation solutions, reducing energy consumption, minimizing waste, and curbing carbon emissions, which aligns with SDG 11 [11]. Secondly, Smart Cities promote economic growth and inclusivity by integrating digital technologies, stimulating innovation, creating job opportunities, and enhancing overall productivity. Inclusive urban planning ensures that marginalized communities benefit from these advancements, contributing to SDG 8 [20], [39]. Thirdly, Smart Cities improve the quality of life for residents by strengthening healthcare systems, innovative infrastructure, data-driven governance, and public services and safety. This directly supports SDG 9 [37]. Finally, Smart City initiatives leverage data analytics to monitor and respond to emerging challenges like the ongoing global pandemic.

Overall, the role of Smart Cities in advancing SDGs is undeniable, and their continued evolution is critical for creating more sustainable, resilient, and inclusive urban environments. As technology progresses, Smart Cities serve as living laboratories for innovative solutions that can be scaled and replicated globally, further contributing to achieving SDGs. In addition, Smart Cities serve as catalysts for achieving SDGs by fostering sustainable development, economic prosperity, social inclusion, and environmental stewardship. The innovative solutions and data-driven approaches of Smart Cities empower communities to address the complexities of the 21st century and build a more resilient and equitable future for society.

6. Conclusions

This study has critically examined the integral role of Smart Cities initiatives in advancing the United Nations Sustainable Development Goals (SDGs) 8, 9, and 11. By adopting a structured literature review approach, the research highlights how technological innovation, sustainable infrastructure, and inclusive socioeconomic growth converge within the Smart City framework to support broader global development objectives. The findings emphasize that Smart Cities are more than technological upgrades; they are transformative platforms that foster employment (SDG 8), promote resilient infrastructure and industrial innovation (SDG 9), and ensure sustainable urban living (SDG 11). The interconnection between digital infrastructure, data-driven governance, and urban sustainability creates synergies that can catalyze measurable progress across key indicators of the SDGs. Moreover, the study provides practical insights for stakeholders, including policymakers, city planners, and social entrepreneurs, on leveraging Smart Cities as catalysts for sustainable change. These insights not only inform decision-making at the municipal and national levels but also offer a foundation for future empirical and policy-oriented research. In conclusion, Smart Cities represent a strategic pathway toward achieving critical global sustainability goals. Their successful implementation requires integrated planning, inclusive participation, and continuous innovation to ensure that urban growth translates into equitable and sustainable development for all.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

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Ethical approval statement

Ethical approval is not applicable for this research.

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Appendix A: Current Status of Countries in Smart Cities and SDGs 8, 9, 11

Current Status of Countries and Cities on Smart Cities (SC)				Current Status of Countries on Sustainable Development Goals (SDGs)			
Country	**Country HDI**	**City**	**SC Ranke**	**SDG Score**	**SDG8**	**SDG9**	**SDG11**
Switzerland	0.962	Zurich	1	79.30	Significant Challenges Remain	Significant Challenges Remain	Challenges Remain
Norway	0.961	Oslo	1	82.23	Significant Challenges Remain	Challenges Remain	Challenges Remain
Australia	0.951	Canberra	3	76.88	Challenges Remain	Challenges Remain	Challenges Remain
Denmark	0.948	Copenhagen	4	85.0	Challenges Remain	Challenges Remain	Significant Challenges Remain
UK	0.929	London	6	82.16	Significant Challenges Remain	Achieved	Significant Challenges Remain
Singapore	0.939	Singapore	7	71.41	Major Challenges Remain	Achieved	Challenges Remain
Finland	0.94	Helsinki	8	86.35	Challenges Remain	Challenges Remain	Challenges Remain
Sweden	0.947	Stockholm	10	85.7	Significant Challenges Remain	Challenges Remain	Challenges Remain
Germany	0.942	Hamburg	11	83.45	Challenges Remain	Challenges Remain	Achieved
China	Beijing	0.907	12	70.85	Significant Challenges Remain	Challenges Remain	Significant Challenges Remain
UAE	0.911	Abu Dhabi	13	70.52	Major Challenges Remain	Challenges Remain	Major Challenges Remain
Czech Rep.	0.889	Prague	14	81.26	Challenges Remain	Significant Challenges Remain	Challenges Remain
Netherlands	0.941	Amsterdam	15	79.21	Significant Challenges Remain	Challenges Remain	Challenges Remain
South Korea	0.925	Seoul	16	77.33	Challenges Remain	Challenges Remain	Significant Challenges Remain
USA	0.921	New York	21	74.43	Significant Challenges Remain	Challenges Remain	Significant Challenges Remain
New Zealand	0.937	Auckland	22	78.81	Challenges Remain	Significant Challenges Remain	Significant Challenges Remain
Iceland	0.959	Reykjavik	26	79.54	Significant Challenges Remain	Significant Challenges Remain	Significant Challenges Remain
Spain	0.905	Bilbao	27	80.70	Significant Challenges Remain	Significant Challenges Remain	Significant Challenges Remain
Austria	0.916	Vienna	28	82.55	Significant Challenges Remain	Challenges Remain	Challenges Remain
Saudi Arabia	0.875	Riyadh	30	64.91	Significant Challenges Remain	Significant Challenges Remain	Major Challenges Remain
Estonia	0.890	Tallinn	32	80.46	Significant Challenges Remain	Significant Challenges Remain	Challenges Remain

Current Status of Countries and Cities on Smart Cities (SC)				Current Status of Countries on Sustainable Development Goals (SDGs)			
Country	**Country HDI**	**City**	**SC Ranke**	**SDG Score**	**SDG8**	**SDG9**	**SDG11**
Belgium	0.937	Brussels	35	80.04	Significant Challenges Remain	Challenges Remain	Challenges Remain
Canada	0.936	Ottawa	40	78.83	Challenges Remain	Challenges Remain	Challenges Remain
Poland	0.876	Warsaw	44	81.69	Challenges Remain	Significant Challenges Remain	Significant Challenges Remain
Luxembourg	0.930	Luxembourg	45	76.81	Significant Challenges Remain	Significant Challenges Remain	Significant Challenges Remain
France	0.903	Paris	46	82.76	Challenges Remain	Challenges Remain	Challenges Remain
Slovenia	0.918	Ljubljana	47	81.34	Significant Challenges Remain	Significant Challenges Remain	Challenges Remain
Italy	0.895	Bologna	51	79.29	Significant Challenges Remain	Major Challenges Remain	Significant Challenges Remain
Qatar	0.855	Doha	59	64.93	Major Challenges Remain	Challenges Remain	Significant Challenges Remain
Ireland	0.903	Lyon	64	78.72	Significant Challenges Remain	Significant Challenges Remain	Challenges Remain
Lithuania	0.875	Vilnius	65	78.12	Significant Challenges Remain	Significant Challenges Remain	Challenges Remain
Japan	0.925	Tokyo	72	79.87	Significant Challenges Remain	Achieved	Significant Challenges Remain
Latvia	0.863	Riga	83	80.99	Challenges Remain	Major Challenges Remain	Challenges Remain
Hungary	0.846	Budapest	87	79.53	Challenges Remain	Significant Challenges Remain	Challenges Remain
Thailand	0.800	Bangkok	88	74.67	Significant Challenges Remain	Significant Challenges Remain	Significant Challenges Remain
Malaysia	0.803	Kuala Lumpur	89	69.32	Challenges Remain	Challenges Remain	Significant Challenges Remain
Turkey	0.838	Ankara	90	70.47	Major Challenges Remain	Significant Challenges Remain	Significant Challenges Remain
Israel	0.919	Tel Aviv	91	73.53	Significant Challenges Remain	Challenges Remain	Challenges Remain
Oman	0.816	Muscat	96	66.11	Challenges Remain	Significant Challenges Remain	Major Challenges Remain
Portugal	0.866	Lisbon	99	80.22	Challenges Remain	Challenges Remain	Challenges Remain
Vietnam	0.703	Hanoi	100	73.32	Significant Challenges Remain	Significant Challenges Remain	Significant Challenges Remain
Indonesia	0.705	Jakarta	102	69.43	Significant Challenges Remain	Significant Challenges Remain	Major Challenges Remain
Romania	0.921	Bucharest	104	76.70	Challenges Remain	Significant Challenges Remain	Challenges Remain

Current Status of Countries and Cities on Smart Cities (SC)				Current Status of Countries on Sustainable Development Goals (SDGs)			
Country	**Country HDI**	**City**	**SC Ranke**	**SDG Score**	**SDG8**	**SDG9**	**SDG11**
India	0.633	Delhi	105	63.99	Challenges Remain	Significant Challenges Remain	Significant Challenges Remain
Croatia	0.858	Zagreb	106	82.19	Challenges Remain	Challenges Remain	Challenges Remain
Egypt	0.731	Cairo	108	69.15	Major Challenges Remain	Significant Challenges Remain	Major Challenges Remain
Bulgaria	0.795	Sofia	111	75.54	Significant Challenges Remain	Significant Challenges Remain	Challenges Remain
Greece	0.887	Athens	113	78.71	Significant Challenges Remain	Significant Challenges Remain	Significant Challenges Remain
Philippines	0.699	Manila	115	67.47	Major Challenges Remain	Significant Challenges Remain	Major Challenges Remain
Cyprus	0.896	Nicosia	117	72.92	Significant Challenges Remain	Significant Challenges Remain	Challenges Remain
Colombia	0.752	Medellin	118	70.30	Major Challenges Remain	Major Challenges Remain	Significant Challenges Remain
Chile	0.855	Santiago	119	77.82	Significant Challenges Remain	Major Challenges Remain	Major Challenges Remain
Pakistan	0.544	Islamabad	120	57.02	Major Challenges Remain	Major Challenges Remain	Major Challenges Remain
Mexico	0.758	Mexico City	121	69.28	Major Challenges Remain	Major Challenges Remain	Major Challenges Remain
Algeria	0.745	Algiers	123	70.47	Major Challenges Remain	Significant Challenges Remain	Significant Challenges Remain
Argentina	0.842	Buenos Aires	124	74.4	Challenges Remain	Significant Challenges Remain	Challenges Remain
South Africa	0.713	Cape Town	125	63.44	Major Challenges Remain	Significant Challenges Remain	Major Challenges Remain
Morocco	0.683	Rabat	126	70.85	Major Challenges Remain	Significant Challenges Remain	Significant Challenges Remain
Costa Rica	0.809	San Jose	127	72.88	Significant Challenges Remain	Major Challenges Remain	Significant Challenges Remain
Brazil	0.754	Sap Paulo	130	73.78	Significant Challenges Remain	Significant Challenges Remain	Challenges Remain
Kenya	0.575	Nairobi	131	62.17	Significant Challenges Remain	Major Challenges Remain	Major Challenges Remain
Nigeria	0.535	Lagos	132	54.58	Major Challenges Remain	Major Challenges Remain	Major Challenges Remain
Peru	0.762	Abuja	133	71.88	Significant Challenges Remain	Significant Challenges Remain	Major Challenges Remain
Jordan	0.720	Amman	135	69.06	Major Challenges Remain	Significant Challenges Remain	Major Challenges Remain

Current Status of Countries and Cities on Smart Cities (SC)				Current Status of Countries on Sustainable Development Goals (SDGs)			
Country	**Country HDI**	**City**	**SC Ranke**	**SDG Score**	**SDG8**	**SDG9**	**SDG11**
Tunisia	0.731	Rio de Janeiro	136	72.53	Major Challenges Remain	Significant Challenges Remain	Challenges Remain
Ghana	0.632	Accra	138	63.05	Significant Challenges Remain	Significant Challenges Remain	Major Challenges Remain
Lebanon	0.706	Beirut	139	Lebanon	Major Challenges Remain	Challenges Remain	Major Challenges Remain
Yemen	0.455	Sana'a	140	46.87	Major Challenges Remain	Major Challenges Remain	Major Challenges Remain
Guatemala	0.627	Guatemala City	141	59.41	Major Challenges Remain	Major Challenges Remain	Major Challenges Remain

Note: Smart City and SDGs Data only available for the above countries and/or independent states
Data Source: Sustainable Development Report [15]; and IMD [45]