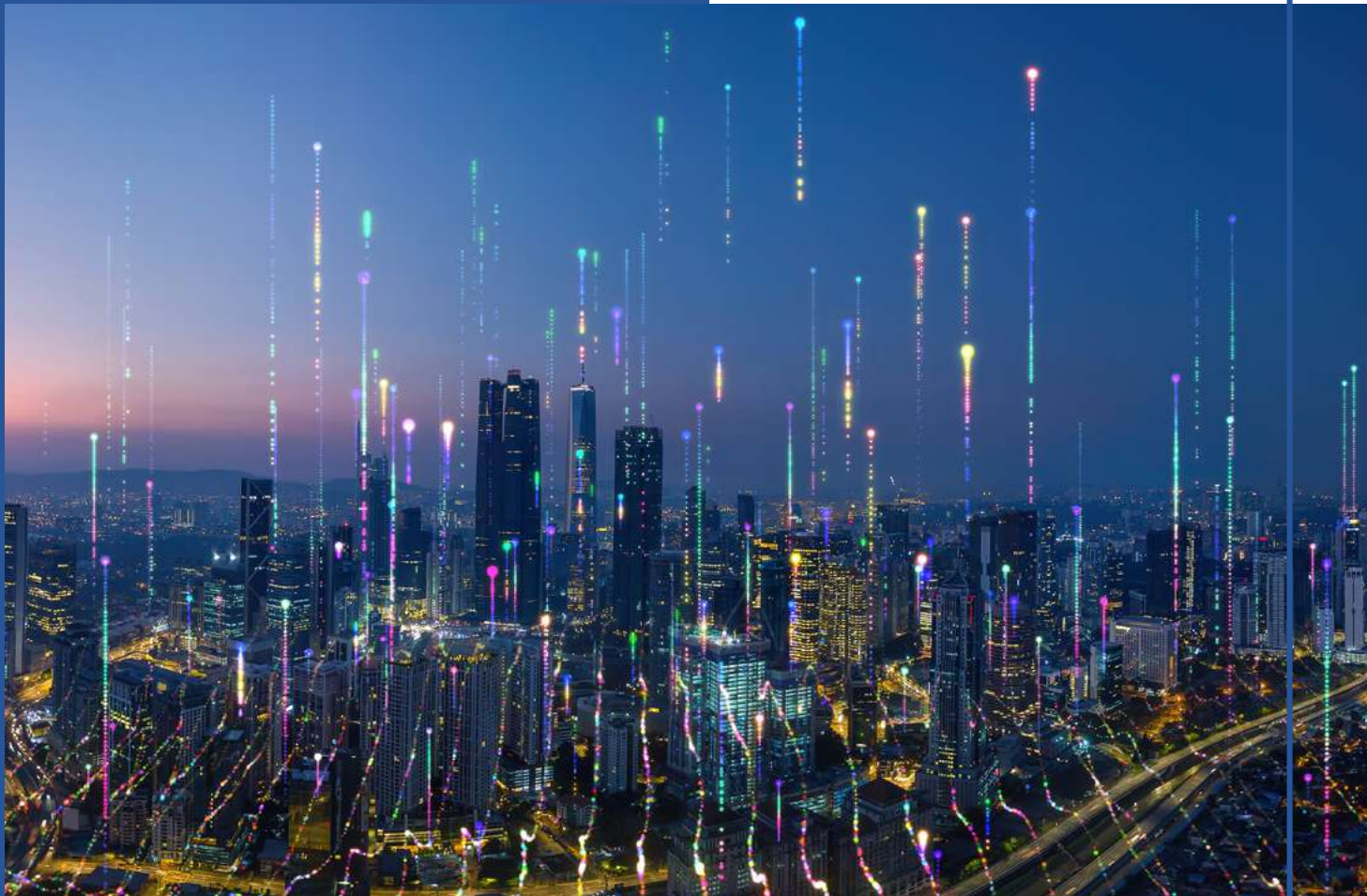




SMART CITIES IN THE DIGITAL AGE: A ROADMAP FOR ETHICAL, INCLUSIVE AND SUSTAINABLE URBAN FUTURES

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EXECUTIVE SUMMARY

Smart cities promise enhanced quality of life, optimal use of resources, and economic innovation by leveraging advanced digital technologies like IoT, AI, and big data. However, the rapid digitalization of urban spaces raises significant challenges, including digital inequality, data privacy concerns, environmental sustainability issues, and the exclusion of vulnerable populations. This paper explores the pivotal role of smart cities in fostering the digital economy while addressing the critical digital technologies' challenges.

Through a Systematic Literature Review (SLR), this novel study identifies these pressing challenges and maps them to the broader dimensions of inclusivity, human-centric development, and sustainability. Furthermore, it provides a strategic roadmap for governments, businesses, private-sector partnerships, and civil societies, emphasizing the importance of equitable access, ethical governance, and sustainable urban planning. By addressing these challenges, smart cities can evolve into inclusive, human-centered ecosystems that drive sustainable growth in the digital economy.



INTRODUCTION

A smart city refers to an urban area that leverages digital technologies to enhance the quality of life, optimize resource use, and ensure sustainability.

It utilizes cutting-edge digital technology tools to improve infrastructure, governance, and public services ^{[1], [2], [3]}. Smart cities aim to create sustainable urban ecosystems that balance technological innovation with social, environmental, and economic objectives ^{[4], [5]}.

The backbone of smart cities lies in digital technologies, such as IoT, AI, cloud computing, and big data. These technologies enable real-time data collection and analysis, facilitating improved decision-

making and city management ^{[6], [7]}. IoT devices monitor various city operations, from traffic management to energy consumption, while AI helps predict urban challenges like congestion and air pollution ^{[8], [9]}.

Smart cities contribute significantly to the digital economy by fostering innovation and creating new business models. The integration of digital technologies enhances productivity, stimulates local businesses, and attracts investment ^[10].

Smart cities are projected to generate revenue of \$ 72.52 billion by 2024 with an expected Compound Annual Growth Rate (CAGR) of 9.72% from 2024 to 2029 ^[11].

Digital technologies offer numerous benefits to smart cities residents, such as automated healthcare, transportation, and education services ^{[12], [13]}; energy-efficient buildings ^{[5], [10]}; and data-driven transparent governance ^{[14], [15]}. The implementation of digital technologies in smart cities enhances the overall quality of life and contributes to a more sustainable digital economy.

However, the deployment of digital technologies in smart cities presents various challenges, including privacy and security concerns, digital inequality, ethical and social issues, and environmental sustainability ^{[2], [16], [17]}. This paper examines these challenges through the broader aspects of inclusivity, human-centric development, and sustainability related to the use of digital technologies in smart cities. It proposes viable solutions, presented as strategic recommendations, to address these challenges and promote a human-centric, all-inclusive, and sustainable digital economy.

We propose a set of strategic recommendations for stakeholders in the digital economy to foster more inclusive, human-centric, and sustainable urban environments in smart cities. For instance, to ensure inclusiveness, governments can implement robust data protection laws, while businesses and Public-Private Partnerships (PPPs) should focus on user-centric designs and public engagement. Moreover, a human-centric approach prioritizes ethical AI use, inclusive public spaces, and participatory feedback mechanisms that reflect community needs.

Besides, sustainability goals can be achieved through interdisciplinary research, green infrastructure, circular economic initiatives, and transparency in environmental claims. Collaborative efforts among smart city stakeholders, including governments, businesses, civil societies, and international organizations, are pivotal in integrating long-term planning, ethical governance, and community resilience into smart city projects, making them truly inclusive, human-centered, and sustainable.

In this article, we adopted a literature review methodology to search, analyze, and consolidate key challenges posed by digital technologies in smart cities. Our contribution lies in bridging research gaps by exploring the interplay between smart cities, the challenges of digital technologies and digital economy. Additionally, we propose strategic recommendations to address these challenges, emphasizing humanity, inclusivity, and sustainability to ensure equitable participation in the smart ecosystem.

Therefore, we formulated the following Research Questions (RQs):

RQ1: How do digital technologies in smart cities pose challenges in terms of inclusivity, humanity and sustainability?

RQ2: What strategic recommendations can help stakeholders address smart city challenges while promoting inclusivity, humanity, and sustainability?



2. BACKGROUND

In this section, we explore the concept of smart cities and digital economy, highlighting their interconnection. We then discuss the benefits of digital technologies in

smart cities and conclude with an overview of the challenges associated with their implementation.

2.1 Smart City Concept

Smart cities add digital intelligence to the urban world and use it to solve public problems and achieve a higher quality of life.

3 layers of "smartness" will elevate life in cities of the future

3.

Adoption and usage, often leading to better decisions and behavior change

2.

Smart applications and data-analysis capabilities

1.

The tech base includes networks of connected devices and sensors

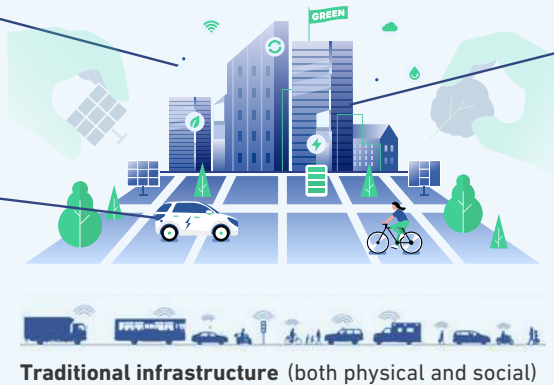


Figure 1:

Evolution of Traditional Infrastructure to Smart Cities ^[15]

Smart cities are revolutionizing urban landscapes by harnessing digital technologies to enhance economic growth and improve quality of life. These innovations not only streamline services and optimize resource allocation but also create new revenue streams, attract businesses, and foster a more engaged community, thus driving the digital economy forward ^{[18], [19], [20]}.

The term "smart city" lacks a universally accepted definition but generally refers to the modernization and digitalization of urban areas to address sustainability challenges and improve urban management amid rapid urbanization and population growth ^{[5], [16], [17]}.

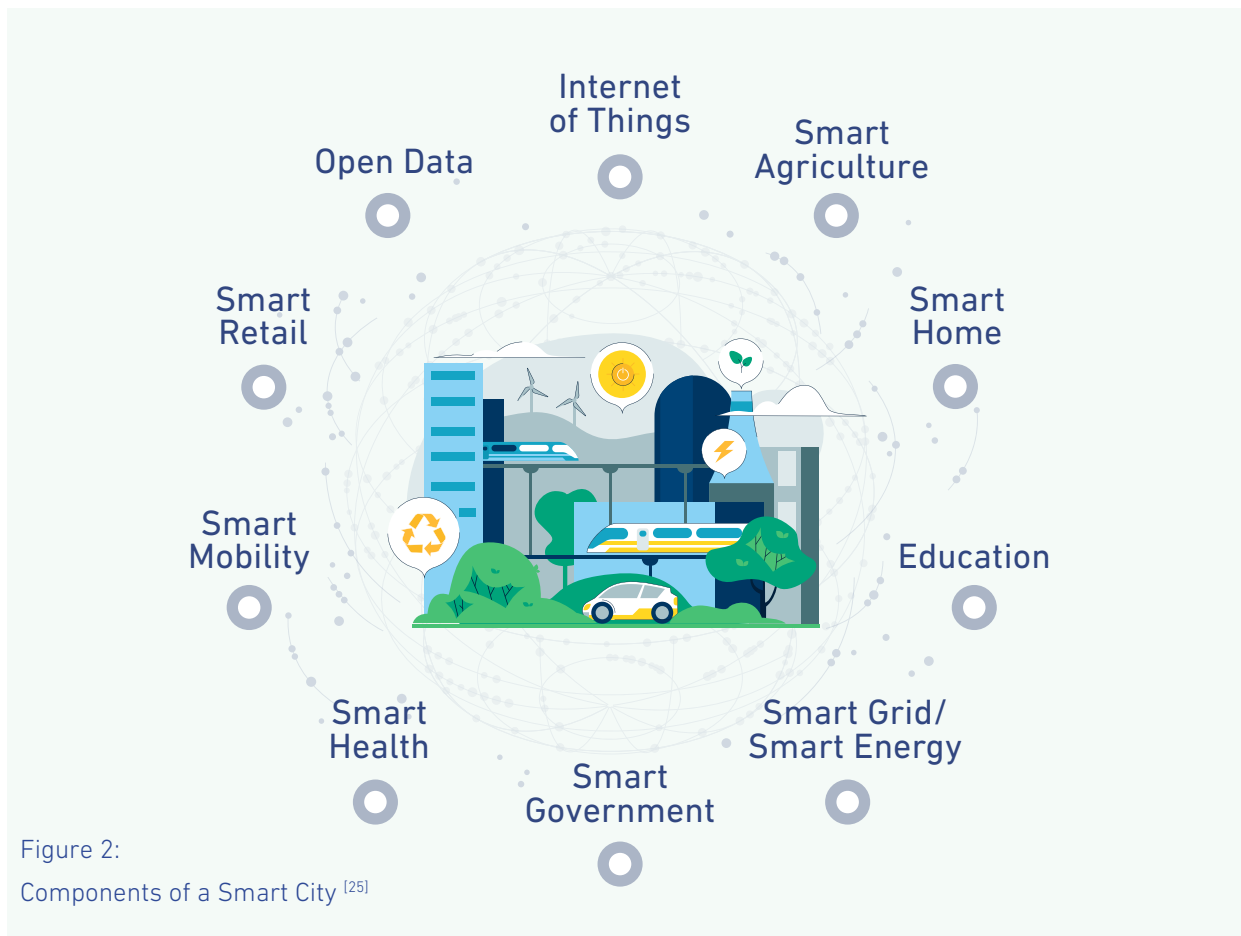
At its core, the smart city concept envisions urban environments as integrated networks, where subsystems, such as transportation,

energy, and waste management, function cohesively using interconnected technologies like sensors, embedded intelligence, and digital platforms ^{[6], [21], [22]}.

Smart cities leverage a combination of hardware (infrastructure), software, and human capital to create more efficient and sustainable living environments ^{[1], [23]}. This transformation of the urban "nervous system" enables enhanced service delivery, decision-making, and management, all of which collectively support the growth of the digital economy ^{[7], [18], [24]}.

The evolution of traditional infrastructure to a technology-driven smart system is depicted in Figure 1 ^[15].

2.2 Use of Digital Technologies in Smart Cities



Smart cities rely on various advanced digital technologies to function effectively. Technologies such as the IoT, AI, big data analytics, and immersive technologies like Augmented Reality (AR) and Virtual Reality (VR) play a central role in smart city initiatives.

These technologies enable real-time data collection, analysis, and communication, enhancing urban infrastructure management, resource allocation, and city planning ^{[8], [9]}.

IoT devices, for instance, help cities monitor and manage traffic, waste, and energy, while AI and big data process vast amounts of information, supporting predictive analytics for challenges like congestion and resource distribution ^{[6], [22]}.

This data-centric approach not only enhances urban efficiency but also strengthens public engagement and decision-making, both of which are key factors in boosting the digital economy ^{[4], [26]}. The various components of a smart city are illustrated in Figure 2 ^[25].

2.3 Smart Cities and the Digital Economy

The digital economy encompasses all economic activities that depend on or are significantly enhanced by digital inputs, including governments that integrate digital technologies inputs into their economic activities ^[27].

The integration of digital technologies in smart cities directly impacts the digital economy by fostering innovation and creating new business opportunities. The digital economy can be defined as “the economic activity reliant on, significantly enhanced, or enabled by digital technologies and their applications. This includes activities that increase human well-being or lead to social or environmental benefits” ^[28].

Simply put, the digital economy refers to economic activities that arise from connecting individuals, businesses, devices, data and operations through digital technology. It encompasses online connections and transactions across multiple sectors and technologies, such as the internet, mobile technology, big data, and information and communications technology.

The digital economy differs from the traditional economy due to its reliance on digital technology, online transactions and its transformative impact on traditional industries ^[29].

Smart cities are projected to generate significant economic value, with annual revenue from related technologies and industries estimated to reach up to \$1.5 trillion by 2025 ^{[11], [15]}.

Digital technologies such as IoT, AI, and big data help streamline services and governance, creating more efficient business environments and enhancing productivity across sectors. Furthermore, smart cities enhance urban living conditions, attracting investments, stimulating local businesses, and generating jobs, all of which drive the growth of the digital economy ^{[10], [18], [30]}.

Figure 3 ^[31] illustrates how digital technologies in smart cities are transforming traditional economies into digital economies.

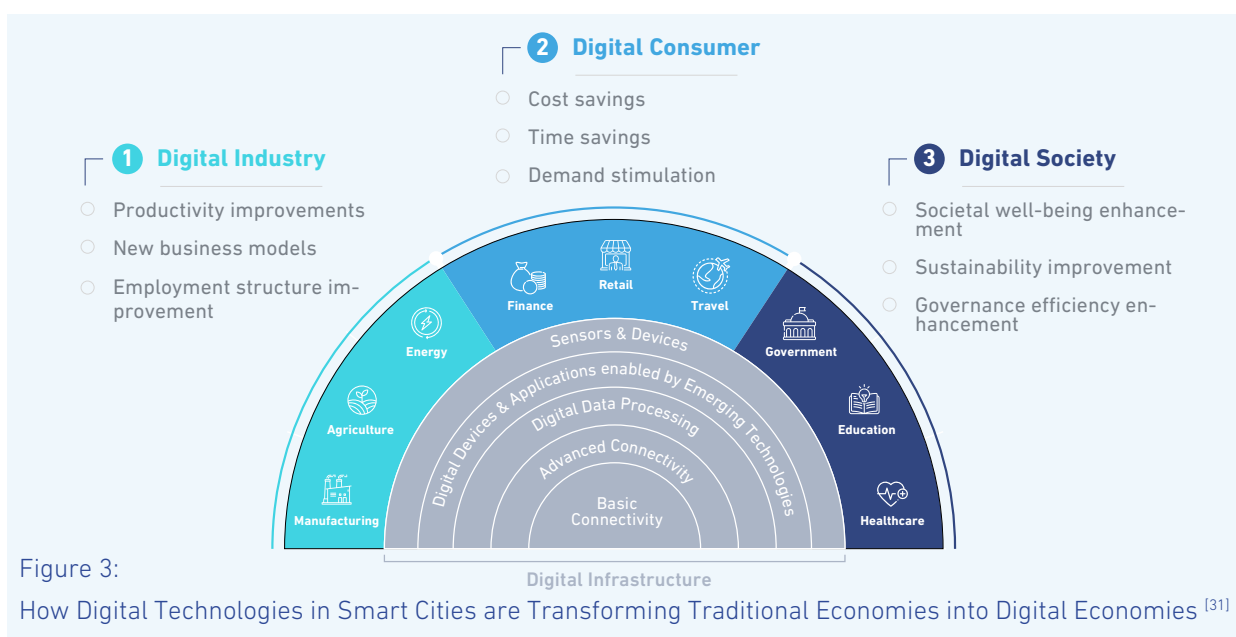


Figure 3: How Digital Technologies in Smart Cities are Transforming Traditional Economies into Digital Economies ^[31]

2.4 Benefits of Digital Technologies in Smart Cities

The use of digital technologies in smart cities offers numerous benefits. First, they improve the quality of life for urban residents by enhancing access to services such as healthcare, transportation, financial technology (fintech), education and utilities [12], [17].

For instance, smart cities have significantly advanced medical services through technologies like telemedicine, electronic health records, and AI-driven diagnostics. Moreover, blockchain technology, mobile banking, digital payment systems, e-commerce, smart portfolios and cryptocurrencies are prominent fintech innovations in smart cities across developed countries [32].

Additionally, the integration of digital technologies in smart cities stimulates economic growth by fostering innovation, improving operational efficiency, and attracting investments [33].

Second, these technologies support sustainability goals by optimizing resource usage and reducing waste. Smart buildings use IoT sensors to monitor and manage energy consumption, boosting efficiency, lowering carbon footprints, and contributing to a greener urban environment [34].

For instance, cities like Barcelona and Copenhagen have successfully implemented smart technologies to significantly reduce energy consumption and carbon emissions, contributing to both environmental sustainability and economic growth [10], [34].

Lastly, digital technologies enable data-driven decision-making, which enhances governance and public service delivery, ultimately driving the broader digital economy [20].

Smart city applications can enhance key quality-of-life indicators by 10–30 % from the time they are introduced, as illustrated in Figure 4 [15]. The figure highlights the key benefits of digital technologies in smart cities by showcasing positive impact across several dimensions of urban life.

Smart city technologies offer speed and convenience by reducing commute times (15–20%) and cutting the time citizens spend interacting with government and healthcare services (45–65%). In terms of safety, technology helps lower fatalities (8–10%), crime (30–40%), and emergency response times (20–35%).

Moreover, smart systems decrease citizen expenditures (1–3%) helping reduce the cost of living. Besides, job and economic opportunities increase with slight growth in formal employment (1–3%).

This figure also illustrates improvements in social connectedness and civic participation, showing that citizens feel more connected to their local community, while government engagement rises by 15–25%.

From an environmental perspective, smart technologies enhance environmental quality by reducing greenhouse gas emissions (10–15%), water consumption (20–30%), and uncollected waste (10–20%).

Similarly, the integration of digital tools in healthcare can help lower the disease burden

by 8–15%, demonstrating the potential for health improvements in smart cities.

In summary, digital technologies play a crucial role in making smart cities more efficient, sustainable, and livable for their residents.

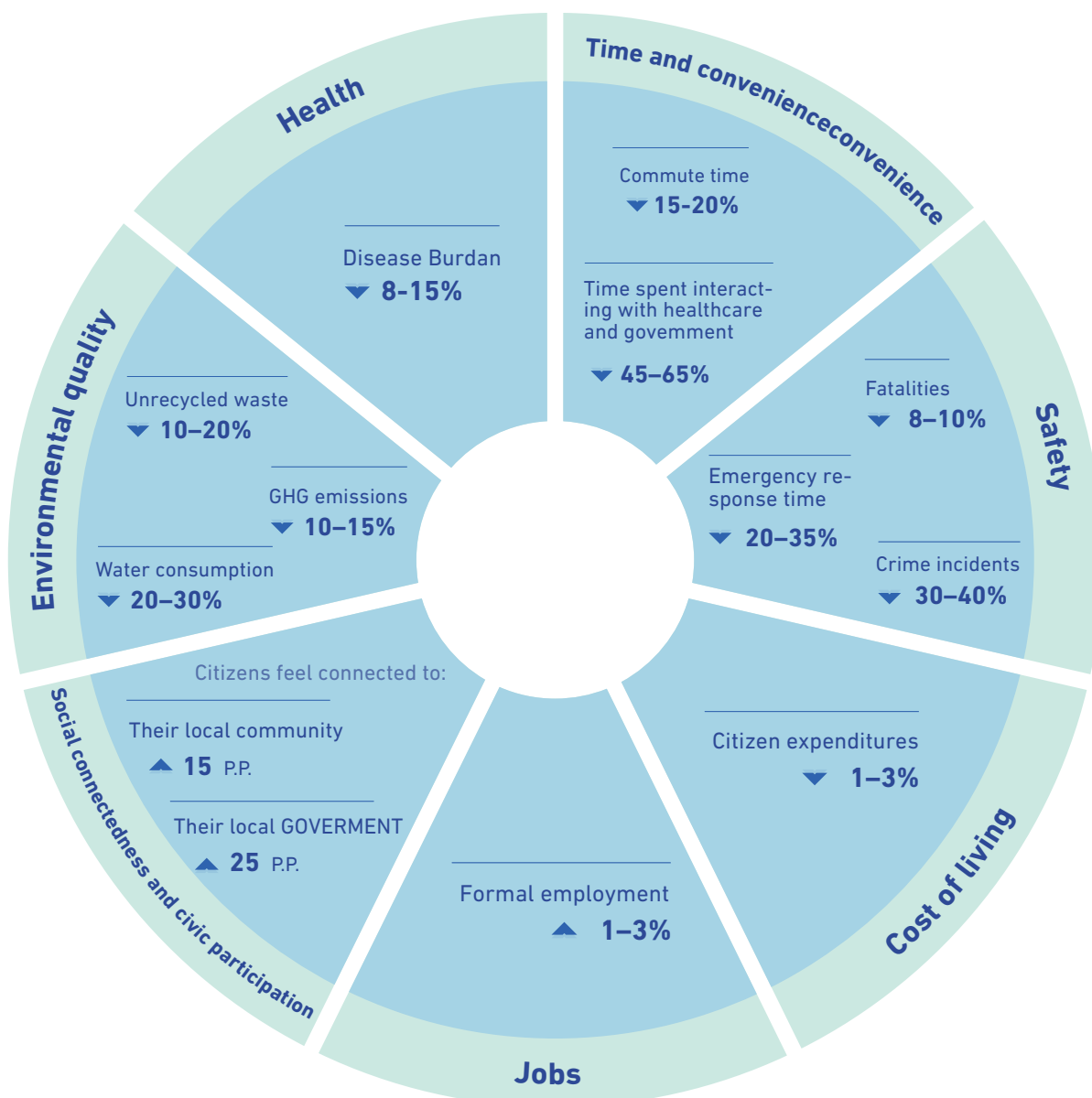


Figure 4:

Smart Cities Become More Efficient with the Integration of Digital Technologies ^[15]

2.5 Challenges of Digital Technologies in Smart Cities



The extensive reliance on digital technology and increased automation in smart cities also presents various challenges, such as data privacy and security, socioeconomic disparity, digital inequality, governance,

and high resources consumption [etc.].

Below, we discuss some of the major challenges associated with technology-driven smart cities:

2.5.1 Privacy and Security of Data

One of the primary concerns related to the use of digital technologies in smart cities is “the privacy and security” of the users’ data. As smart cities increasingly rely on IoT devices and big data, the risk of cyberattacks and data breaches continues to rise, threatening both individual privacy and public safety ^[2].

Another critical issue is the potential misuse of surveillance technology by governments in smart cities, which could be used to control people without proper oversight, thereby compromising personal freedom.

The large-scale collection of public data by government agencies also raises privacy concerns, as citizens’ personal information could be misused or insufficiently protected.

Additionally, inadequate cybersecurity measures in smart cities can diminish citizens’ confidence in sharing personal information, ultimately eroding trust in digital services.

This lack of trust may slow the adoption of smart city initiatives and, eventually, hinder the development of inclusive, secure, and sustainable digital economy ^{[3], [6], [7]}.

2.5.2 Digital Divide

The digital divide is another significant challenge in the context of smart cities, where technological advancements often widen existing social disparities. It primarily refers to the gap between individuals or groups who have access to digital technologies, such as the internet and computers, and those who lack access.

This divide leads to digital inequality, a related phenomenon that highlights how social factors such as income, education, and location influence an individual's ability to benefit from digital resources ^[35].

Research indicates that while smart city initiatives aim to enhance urban efficiency and sustainability, they often benefit affluent communities with greater access to digital resources and technologies, while marginalized groups fall behind ^{[16], [36], [36]}.

Consequently, smart city developments may unintentionally perpetuate existing inequalities rather than mitigate them, as those without access to digital technologies fall behind in terms of both infrastructure and services ^{[26], [37]}.

2.5.3 Ethical and Social Challenges

Smart cities face significant ethical and social challenges stemming from the use of digital technologies such as AI, cloud computing, big data, and facial recognition systems, which match human faces from digital photos or videos against large databases of faces.

However, these technologies raise concerns regarding surveillance, data ownership, and algorithmic bias, necessitating the establishment of robust ethical governance frameworks to protect citizens' rights and ensure the equitable use of digital technology ^{[17], [24], [38]}.

Additionally, ethical frameworks governing AI in smart cities are still underdeveloped, leaving room for biases in decision-making processes and potential discrimination against certain populations ^[39]. Concerns also arise regarding who controls and benefits from these technologies, especially when private companies hold significant power over urban infrastructure.

2.5.4 Environmental Sustainability

Smart cities face various environmental sustainability challenges such as energy management, air and water quality, suburban sprawls and natural resource conservation. Environmental sustainability in smart cities is compromised by factors such as rapid technological advancement, escalating consumption patterns, limited recycling and repair infrastructure, shorter product lifespans, and an overall increase in electronic dependency.

While smart technologies can optimize resource utilization, they also drive greater energy consumption and increase electronic waste (e-waste) generation. Balancing technological innovation with environmental sustainability remains a pressing challenge for urban planners ^{[5], [12]}.

Moreover, the intensive energy demands of AI-driven data centers amplify environmental concerns. For instance, the widespread use of large language models like ChatGPT has intensified worries over carbon emissions and water consumption due to their substantial resource use throughout both training and operational phases ^[40]. Additionally, environmentalists criticize the ecological footprint urban projects like Songdo, South Korean, emphasizing that unchecked urban expansion threatens biodiversity and natural ecosystems^[41].

2.5.5 Limited Digital Literacy

The successful implementation of smart city technologies depends on a digitally literate population. However, digital illiteracy among residents presents significant obstacles to fully leveraging urban technological advancements. As cities increasingly integrate digital technologies to enhance services and governance, a substantial portion of the population lacks the necessary skills to engage with these innovations effectively ^{[8], [42]}.

For instance, a study highlights that many smart cities residents lack the digital proficiency required to efficiently use digital tools ^[43]. This gap not only limits access to essential services but also weakens the overall effectiveness of smart city initiatives designed to promote inclusivity and sustainability.

Furthermore, the extensive reliance on digital technologies can alienate vulnerable groups, such as the elderly and low-income individuals, who may struggle to navigate digital platforms ^[44].

2.5.6 Lack of International Cooperation

The lack of global cooperation at the international level among nations, and their societies presents a significant challenge to the development of smart cities ^{[45], [46]}. As urban areas increasingly adopt digital technologies to address complex societal issues, the absence of a cohesive global framework leads to fragmented efforts and missed opportunities for knowledge sharing.

For instance, the International Urban Cooperation (IUC) program emphasizes the need for cities worldwide to collaborate in tackling common challenges such as climate change and urbanization pressures ^[47]. Furthermore, the OECD warns that without transparent and inclusive approaches, smart city initiatives may inadvertently deepen existing inequalities, as cities lacking international support struggle to implement comprehensive solutions ^[48].

This lack of coordination can lead to inefficiencies and missed opportunities to implement successful models from other regions, ultimately slowing progress toward sustainable urban development.

2.5.7 Algorithmic Bias

Algorithmic bias occurs when AI-driven systems make decisions that systematically disadvantage certain groups within a smart city. This bias often stems from underrepresentation of certain demographics in the data used to train AI algorithms or from pre-existing cultural biases embedded in the data ^[49].

Algorithmic bias poses serious risks in critical sectors like healthcare, credit scoring, and criminal justice. Hence, algorithms used in smart cities can inadvertently reinforce existing societal biases. For instance, facial recognition technology and predictive policing algorithms may disproportionately affect underserved communities, leading to biased treatment and reinforcing social inequalities. These biases result in unfair analyses when algorithms are trained on skewed data ^{[50], [51]}. Consequently, algorithmic biases embedded in AI systems can disproportionately harm underrepresented communities, potentially amplifying existing social disparities ^[52].

2.5.8 Energy Resource Demands

Advances in digital technology used in smart cities pose a major challenge: ensuring a continuous power supply while optimizing limited energy resources, including nuclear, fossil fuels, and renewables. The increasing reliance on digital infrastructure has significantly escalated energy consumption in smart cities.

Digital technologies such as IoT devices, data centers, sensors, and AI, particularly GenAI models like Large Language Models (LLMs) require substantial electricity to function without interruption ^[53].

Overall, cities consume around 78% of the world's energy ^[54], and digital technologies account for 8-10% of global energy consumption ^[55]. Thus, the growing energy demands to sustain these technologies can be detrimental to the environment especially when renewable energy sources are not effectively integrated ^[56].

2.5.9 Exclusion of Vulnerable Populations

Vulnerable groups in a society include the elderly, individuals with disabilities, low-income populations, the illiterate, ethnic or racial minorities and migrant workers. These marginalized populations are often excluded from the benefits of smart city technologies.

For instance, prioritizing high-tech solutions may lead to investments that favor wealthy neighborhoods over poorer ones. As a result, resources and services become unequally distributed, further widening socioeconomic disparities particularly in areas such as healthcare, education and public services ^{[57], [58]}. Similarly, India's initiative to create 100 smart cities reportedly displaced low-income communities without providing adequate alternative housing solutions for those affected ^[59].

2.5.10 Greenwashing

Some technology-driven projects in smart cities are marketed as environmentally sustainable but fail to deliver measurable environmental benefits. This phenomenon is termed as "greenwashing".

Greenwashing occurs when organizations present misleading or even false information to create the illusion of sustainability ^[60]. This practice is often used to attract investments and improve public perception without generating real ecological impact. Greenwashing projects typically claim to be environmentally friendly and promise to provide "green energy" to smart cities, but such claims often fail to materialize ^{[61], [62]}.

2.5.11 Lack of Access (Availability and Affordability)

Smart city technologies often remain inaccessible to low-income populations due to their high costs, restricting equitable access. The lack of affordable digital technology solutions in public infrastructure further marginalizes disadvantaged groups in the digital economy^[63]. This inaccessibility leads to unequal distribution of benefits, making smart cities appear more like exclusive luxuries than essential innovations^{[64], [65]}.

This issue also undermines the sustainability goals of smart cities. Moreover, more than 5 billion mobile phones were discarded in 2022, yet 40% of the world's low-income population cannot afford basic information and communication technology (ICT) products and services^[66].

2.5.12 Reduced Face-to-Face Interactions

The increasing automation of services and growing reliance on digital technology in smart cities can diminish face-to-face interactions among citizens, potentially leading to social isolation. Over time, this decline in human connection can weaken community bonds and create a more socially fragmented urban environment. The shift toward remote services could also negatively impact mental health by limiting opportunities for social engagement^{[67], [68]}.

2.5.13 Increase in E-Waste

The rapid advancement of technology in smart cities has led to a growing volume of electronic waste (e-waste). E-waste refers to discarded electronic devices that contain toxic additives or hazardous substances, such as mercury, which pose serious risks to human health.

The shortened life cycles of smart devices, combined with frequent upgrades, contribute to the rapid accumulation of e-waste, creating significant environmental and health hazards if not properly managed. This challenge is further exacerbated by inadequate recycling infrastructure in many parts of the world^{[69], [70]}.

E-waste management in smart cities remains a pressing concern due to the increasing volume of discarded electronic devices as urbanization and digitalization accelerate. By 2030, global e-waste production is projected to reach 82 million tons, yet the affordability of ICT products and services remains a key challenge in the digital economy^[71].

2.5.14 Resource Inefficiency

Smart cities that fail to optimize their digital infrastructure suffer from significant resource inefficiencies. Ineffective management of digital technologies like data centers and smart grids leads to excessive resource consumption, undermining the sustainability these systems aim to promote. Poor resource allocation further contributes to wasted energy and financial losses^[72].

2.5.15 Short-Term Planning

Many smart city initiatives prioritize rapid technological advancements without adequately considering long-term environmental impacts. This lack of foresight can lead to unsustainable urban development, as infrastructure quickly becomes obsolete or fails to address future environmental challenges. A short-term focus often emphasizes immediate returns over long-term sustainability [73], [74].

2.5.16 Technology Dependency

As smart cities become increasingly reliant on digital technology, the risk of system failures rises sharply. If critical services depend too heavily on technology, failures in these systems can cause severe disruptions. A single point of failure, such as a widespread outage, can cripple essential services, revealing the fragility of these systems. Major technology failures underscore the need for more resilient digital infrastructure [75], [76].

2.5.17 Lack of Representation in Data

Big data in smart cities refers to the collection, analysis, and utilization of vast amounts of data generated through interconnected devices, sensors, and urban infrastructure. It plays a crucial role in optimizing urban operations and by analyzing this data, city administrators can make informed, data-driven decisions to improve efficiency, reduce costs, and enhance the quality of life for residents.

However, managing such datasets presents significant challenges for smart city stakeholders [53].

One major challenge is the underrepresentation of minority populations. Marginalized groups such as individuals with disabilities, the elderly, migrants, low-income populations, and racial or ethnic minorities, are often excluded from smart city datasets, leading to decisions that fail to adequately address their needs.

This lack of representation can exacerbate social disparities, as the exclusion of these communities from data-driven processes risks deepening existing inequalities rather than alleviating them [2], [77].

These challenges are closely tied to broader aspects of inclusivity, humanity and sustainability in smart cities. For instance, privacy, security, and ethical concerns fall within humanity, while inclusivity include inequality and the digital divide.

Likewise, sustainability may encompass environmental challenges, the digital literacy gap, and lack of international cooperation.



3. RESEARCH GAPS

Despite advancements in smart cities, significant research gaps remain, presenting opportunities for deeper exploration in this field.

First, there is a lack of comprehensive studies that systematically identify the key challenges arising from digital technologies in smart cities while linking them to broader aspects such as inclusivity, humanity, and sustainability [16], [17], [45].

Second, although some studies provide technical solutions for specific smart cities challenges, such as improving cybersecurity or minimizing e-waste, there is limited research on developing strategic recommendations for stakeholders that

align with the core values of inclusivity, human-centered design, and sustainability in smart city development [6], [78].

Third, existing literature seldom explores the intersection of smart cities, digital technology challenges, and the digital economy simultaneously.

This study aims to bridge these gaps by identifying the key challenges, proposing comprehensive recommendations for smart city stakeholders, and fostering an integrated dialogue across these interconnected fields.



4. RESULTS AND FINDINGS

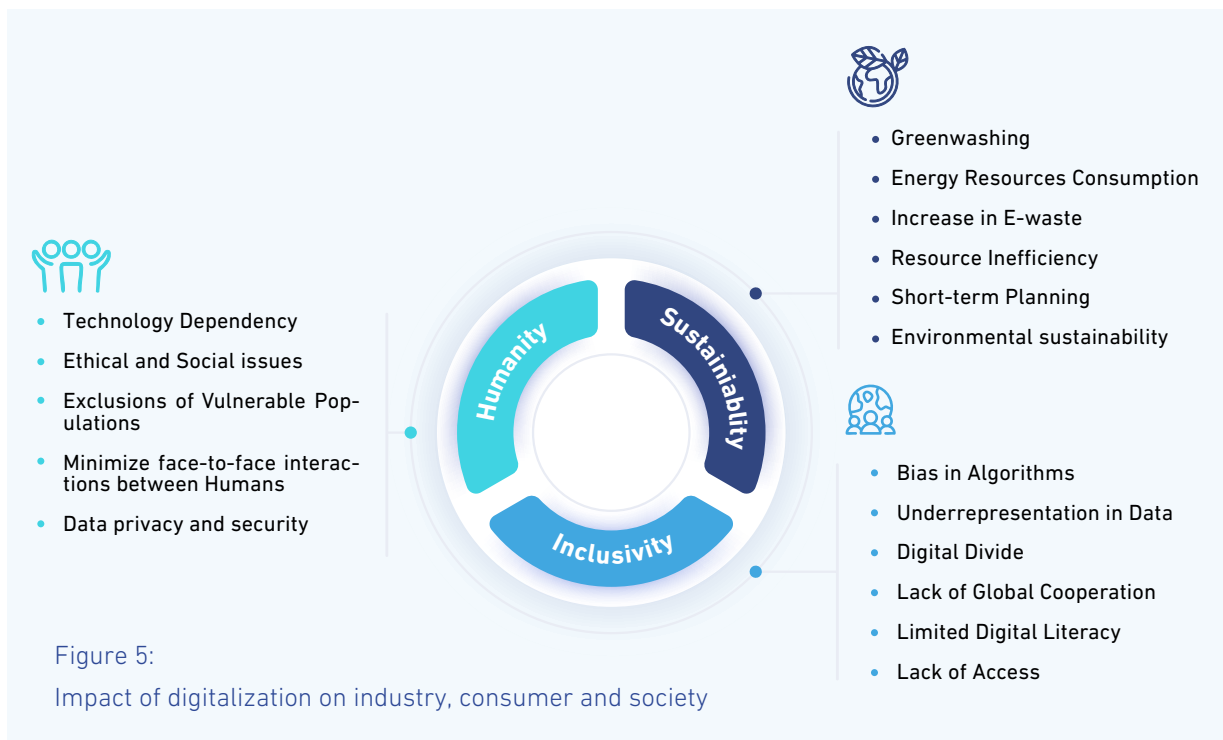
In this section, we present the results and findings from our analysis of the key challenges identified in existing literature on

smart cities. accordingly, we aim to address our two Research Questions (RQs) below:

4.1 RQ1: Digital Technologies Challenges in Smart Cities Regarding Inclusivity, Humanity, and Sustainability

Our review and analysis of the literature on the interconnection between smart cities, the use of digital technologies, and the digital economy enabled us to map the challenges of digital technologies to the three broader aspects of inclusivity,

humanity and sustainability. As shown in Figure 5, this mapping offers key insights into our RQ1, demonstrating how digital technologies in smart cities pose challenges in these three areas. We elaborate on our response to RQ1 as follows:



4.1.1 Inclusivity

Inclusivity refers to ensuring fair and equal access to opportunities and resources for all individuals in society, regardless of their background, abilities, or circumstances. It emphasizes openness, accessibility, and equality, ensuring that diverse voices and perspectives are recognized and valued ^[79].

In the context of smart cities, inclusivity requires deliberate efforts to ensure that all citizens—especially marginalized groups such as the elderly, people with disabilities, low-income communities, and those with limited digital literacy—benefit from urban innovations. This entails designing digital infrastructure, public services, and technologies that are both accessible and affordable to all ^[48].

Despite the importance of inclusivity in smart cities faces several challenges, including the digital divide, limited digital literacy, algorithmic bias, restricted access to digital technologies, underrepresentation in data, and a lack of global cooperation.

If left unaddressed, these challenges could exclude vulnerable groups from essential digital services, deepening social inequalities, and impeding the development of an inclusive and sustainable digital economy ^{[37], [80]}.

Building upon these concerns, the inclusivity-related challenges in today's smart cities highlight the urgent need for equitable access and representation. Several real-world examples illustrate the inclusive challenges in smart cities.

For example, Amsterdam's predictive policing algorithms have demonstrated bias by disproportionately targeting certain neighborhoods, exacerbating existing social inequities ^[81]. Similarly, the digital divide remains a critical issue, as seen in Nairobi's informal settlements, where limited internet access isolates low-income communities from smart city benefits ^[82].

Limited literacy and access to digital technology further deepen these inequalities, excluding vulnerable communities from the digital ecosystem. During the COVID-19 pandemic, the shift toward digital governance in Seoul intensified this issue, as individuals with limited digital literacy, particularly the elderly and marginalized groups were disproportionately excluded from essential services ^[83].

This demonstrates how rapid technological shifts can inadvertently marginalize those most in need of support.

This issue is also linked to underrepresentation in data, another major barrier to digital inclusivity. For instance, in New York City, racial minorities have raised concerns about their lack of representation in datasets used for smart city planning, leading to policies that fail to reflect their realities ^[78].

These examples illustrate how biased algorithms, unequal access, and data gaps can create discriminatory environments in smart cities, hindering inclusive urban development.

4.1.2 Humanity

The concept of humanity emphasizes the need to preserve fundamental human values such as privacy, dignity, social connections, and well-being in the face of technological change. It underscores the importance of designing digital systems that prioritize ethical principles, foster social trust, and maintain the essence of human interaction, ensuring that individuals and communities remain engaged rather than alienated amid urban innovation ^[84].

In the context of smart cities, humanity remains a crucial concern as digital technologies, while offering efficiency and convenience, also introduce significant ethical and social challenges. One major issue is data privacy and security.

Smart city infrastructures rely heavily on surveillance systems and IoT devices, leading to the widespread collection of personal data, often without adequate transparency or consent. In Barcelona, for example, smart city initiatives raised concerns when citizens' personal data was gathered for urban management without sufficient safeguards to ensure privacy protection ^[85]. Such practices threaten individual freedoms, making privacy violations a central ethical dilemma for smart cities ^[52].

Furthermore, overdependence on technology in smart cities can weaken face-to-face interactions, eroding community ties and social cohesion.

In Tokyo, for instance, the extensive use of digital platforms for public services has contributed to a sense of isolation among older residents, who struggle to engage meaningfully in the absence of personal interaction ^[86]. This excessive reliance on digital technology not only diminishes human connections but also exposes cities to significant risks during IT system failures, as witnessed in cases of major outages ^[75].

These challenges highlight the need for a balanced approach to smart city development, where technological innovation aligns with human values, ensuring that the pursuit of efficiency does not come at the cost of social well-being and ethical responsibility.

4.1.3 Sustainability

Sustainability refers to meeting present needs without compromising the ability of future generations to meet their own. It involves balancing economic growth, environmental care, and social well-being ^[87].

In the context of smart cities, sustainability ensures that technological advancements support the environment, making cities more resilient, energy-efficient, and resource-conscious. However, smart cities face significant challenges that can undermine their environmental goals. Key concerns include increased energy consumption, greenwashing, rising e-waste, resource inefficiency, environmental degradation, and short-term planning threaten the sustainability of smart cities.

The most pressing challenge in developing sustainable smart cities is their high energy consumption. While technologies like IoT and data centers improve urban efficiency, they also require vast amounts of energy.

In Singapore, for instance, the growing reliance on digital infrastructure, including data centers, has placed considerable strain on existing energy resources, raising concerns about the sustainability of its smart city model ^[88].

Without efficient energy management, such initiatives may exacerbate environmental degradation rather than alleviate it. Another issue is greenwashing—the practice of presenting projects as environmentally sustainable without measurable environmental benefits. For example, Toronto's Sidewalk Labs, a high-profile smart city project, was criticized

for making ambitious sustainability claims without achieving tangible improvements, eventually leading to its discontinuation ^[77].

This example illustrates how some smart city initiatives leverage sustainability rhetoric to attract support but fail to achieve meaningful environmental outcomes ^[89].

The rapid adoption of IoT and other digital technologies in smart cities has intensified the growing problem of e-waste. For example, in Chinese cities, the widespread use of smart technologies has led to a surge in e-waste, posing significant environmental hazards when improperly managed ^[90].

Additionally, the constant upgrading and disposal of technological devices have contributed to the increasing volume of discarded electronics, further complicating waste management efforts ^[74].

Another pressing challenge is short-term planning, where smart city projects prioritize immediate technological advancements without considering long-term environmental sustainability.

A focus on short-term gains often leads to resource inefficiency, as digital solutions are deployed without fully optimizing their environmental impact. This narrow-sighted approach neglects future environmental costs, making it difficult for cities to meet their sustainability goals ^[91].

These challenges illustrate the delicate balance smart cities must maintain between technological innovation and environmental sustainability. Achieving lasting sustainability demands that smart cities move beyond promises of green initiatives and develop

robust frameworks that ensure energy-efficient, low-impact technologies while simultaneously tackling the growing e-waste problem and planning for long-term environmental resilience.

4.2 RQ2: Strategic Recommendations for Stakeholders to Address Challenges in Smart Cities

We have identified the key challenges of digital technologies in smart cities and mapped them with the three foundational aspects of inclusivity, humanity and sustainability, which are crucial for the successful development and implementation of smart city initiatives.

Addressing these challenges demands a comprehensive approach that integrates digital technology, policy reforms, and community-driven solutions. Therefore, to address our RQ2, we propose the following strategic recommendations for stakeholders to tackle digital technology challenges and enhance inclusivity, humanity, and sustainability in smart cities.

4.2.1 Recommendations for an Inclusive Urban Environment in Smart Cities

Enhancing inclusivity in smart cities necessitates addressing critical challenges such as the digital divide, limited digital literacy, algorithmic bias, lack of access to technology, underrepresentation in data, and insufficient global collaboration. Below are key recommendations for stakeholders to foster inclusivity in smart cities:

Governments

01 Inclusive Policies: Develop equitable policies that ensure underserved communities gain access to digital infrastructure, such as reliable internet in low-income areas, as emphasized by researchers in ^[82] for inclusive urban smart cities.

02 Digital Literacy: Implement community-led training programs focused on reaching marginalized populations, to improve digital literacy, empowering them to actively participate in smart cities, as supported by authors of ^{[92], [93]} to enhance inclusivity in smart cities.

Businesses

01 Design for Inclusivity: Encourage technology companies to adopt inclusive design principles, ensuring accessibility for all users. Conducting usability testing with underrepresented populations helps identify the needs of marginalized communities, supporting the development of digital products and services that promote inclusivity in smart cities, as proposed by researchers in ^{[94], [95]}.

02 Transparent Data Practices: Advocate for transparent data collection and algorithmic accountability to mitigate biases in smart city technologies. Establish guidelines that require companies to assess the representativeness of the data used in AI systems to prevent bias and discrimination among diverse populations segments, following recommendations from practitioners in ^{[96], [97]} for inclusive urban environments in smart cities.

Public Private Partnerships (PPPs)

- 01 **Community Involvement:** Engage local communities, including the private sector in the planning and execution phases of smart city projects to ensure urban development meets diverse needs. This approach is supported by practitioners in ^[98], who emphasize community engagement for fostering inclusive smart cities.
- 02 **Open Data Platforms:** Facilitate open data access to promote citizen participation and empower them to contribute to urban analytics, addressing underrepresentation in urban data, and improving analytics, as suggested by authors in ^[99], ^[100], to develop inclusive urban environments in smart cities.

Academic Institutions and Researchers

- 01 **Broaden the Scope of Research:** Academic institutions should partner with smart city developers to prioritize research on the socioeconomic impacts of smart city technologies on marginalized communities. This collaboration should also explore how these technologies can advance social equity and resilience, aligning with the recommendations of practitioners in ^[37], ^[101], for creating inclusive smart cities.
- 02 **Collaborate Internationally:** Leading universities and institutions should collaborate with international counterparts to share best practices and develop frameworks for inclusive smart city initiatives, fostering cross-border learning and innovation as highlighted by scholars in ^[102] for enhancing inclusivity in smart cities.

Civil Societies

- 01 **Increase Awareness:** Advocate for the rights of underrepresented communities by facilitating dialogue between residents and policymakers, as advised by authors in ^[103], to promote the inclusive urbanization of smart cities.
- 02 **Support Local Initiatives:** Empower residents through grassroots efforts to expand digital access and literacy, fostering active community involvement in urban development projects to build inclusive smart cities.

International Organizations

- 01 **Market Successful Models:** Document and share best practices from global inclusive smart city projects to address digital disparities, as suggested by ^[97], for enhancing inclusivity in smart cities.
- 02 **Capacity-Building Programs:** Develop and implement capacity-building initiatives to strengthen technical skills, digital literacy, and community engagement in marginalized populations, as advised by ^[104], ^[105], to promote inclusivity in smart cities.

Through collaborative efforts, smart city stakeholders can apply these strategies to create equitable, inclusive urban environments that drive digital economic growth.

4.2.2 Recommendations for a Human-Centered Urban Environment in Smart Cities

Building human-centered smart cities requires addressing the data privacy concerns along with social and ethical challenges. The following strategic recommendations are proposed for stakeholders to achieve this goal:

Governments

- 01 Data Protection Laws:** Enforce stringent data privacy regulations to protect citizens' information and enhance trust in digital systems, as emphasized by researchers in ^[106] and ^[52], to foster human-centric smart cities.
- 02 Ethical AI:** Develop ethical frameworks to ensure fairness, accountability, and transparency in digital technologies, such as AI and data analytics, as suggested by practitioners in ^[2], ^[39], to create human-centric urban environments in smart cities.

Businesses

- 01 User-Centric Solutions:** Prioritize designing digital solutions that are human-centric and align with fundamental values, effectively addressing users' concerns, as proposed by researchers in ^[107], to foster human-centered smart cities.
- 02 Privacy-by-Design:** Embed privacy measures into the early stages of technology development to enhance user trust, aligning with recommendations from ^[108], to promote human-centered smart cities.

Public Private Partnerships (PPPs)

- 01 Inclusive Public Spaces:** Design urban spaces that promote community engagement and social interaction, such as mixed-use developments that facilitate face-to-face interactions among diverse populations in smart cities, as recommended by scholars in ^[109], to foster human-centered smart cities.
- 02 Feedback Mechanisms:** Establish participatory frameworks to incorporate feedback from diverse groups, ensuring smart cities remain responsive to community needs, as suggested by researchers in ^[110], to support the evolution of smart cities with human-centered environments.

Academic Institutions and Researchers

- 01 **Interdisciplinary Research:** Advance research on human-centric challenges such as privacy and ethics to better meet the needs of diverse communities, aligning with the findings of scholars in ^[111], to enhance human-centered urbanization in smart cities.
- 02 **Community-Centric Studies:** Prioritize studies that amplify marginalized voices, ensuring smart city solutions meet the needs, as recommended by researchers in ^[101], for human-centric smart cities.

Civil Societies

- 01 **Advocate for Vulnerable Populations:** Highlight the rights of underserved groups, ensuring their needs and interests are prioritized in smart city development, as suggested by practitioners in ^[112], for the ethical urbanization of smart cities.
- 02 **Community Engagement:** Conduct workshops on data privacy and ethical technology use to cultivate human-centric ecosystems in smart cities, as advocated by researchers in ^[97].

International Organizations

- 01 **Invest in Smart Solutions:** Fund digital initiatives that strengthen health, safety, education and justice systems in smart cities, as proposed by researchers in ^[113], to foster human-centered urban environments.
- 02 **Ethical Standards:** Develop ethical standards and guidelines that prioritize a human-centered approach to smart city technology implementation, ensuring data privacy, ethical governance, and protection against digital exploitation, as highlighted by ^[107] for ethical urbanization in smart cities.

By implementing these strategic recommendations, stakeholders can ensure that smart cities place human values and community engagement at the forefront, fostering ethical environments that support thriving digital economies.

4.2.3 Recommendations for a Sustainable Urban Environment in Smart Cities

To promote sustainability in smart cities and address the related challenges such as rising energy consumption, greenwashing, e-waste accumulation, resource inefficiency, environmental degradation, and short-term planning, smart city stakeholders can implement the following strategic recommendations:

Governments

- 01 Sustainability Policies:** Enact comprehensive regulations and policies that promote energy efficiency, renewable energy, and waste reduction, while also encouraging the adoption of green technologies. These policies should include incentives such as tax breaks for energy-efficient buildings and renewable energy projects, as proposed by authors in ^[114], to foster sustainable smart cities.
- 02 Combat Greenwashing:** Develop transparent reporting mechanisms and standards to hold companies accountable for their environmental claims. This should include adopting standardized metrics for measuring sustainability and requiring companies to disclose data on their environmental impacts in smart cities, as suggested by researchers in ^[115], to promote sustainability in smart cities.

Businesses

- 01 Energy Efficient Products:** Design energy-efficient technologies that integrate renewable energy solutions in smart cities, as advocated by authors in ^[74], to advance sustainable urbanization in smart cities.
- 02 Circular Economy:** Establish recycling targets, adopt sustainable production practices and encourage manufacturers to take responsibility for product life cycles, as emphasized by researchers in ^{[70], [90]}, to promote long-term sustainability in smart cities.

Public Private Partnerships (PPPs)

- 01 Sustainable Design Principles:** Invest in green infrastructure such as parks, green roofs, and permeable surfaces to enhance biodiversity and reduce urban heat, as suggested by researchers in ^[116], supporting sustainability in smart cities.
- 02 Long-Term Planning:** Develop comprehensive long-term strategic plans that emphasize climate resilience and resource conservation, aligning with the recommendations of experts in ^[73], to ensure sustainable smart city development.

Academic Institutions and Researchers

- 01 Sustainability Research:**
Engage in interdisciplinary research involving energy efficiency, e-waste management, and the environmental impacts of urbanization, as highlighted by researchers in ^[5] and ^[113], to enhance the sustainability of smart cities.
- 02 Knowledge Sharing:**
Foster partnerships among academia, industry, and governments to exchange leading sustainable practices, as proposed by authors in ^[117], facilitating the adoption of innovative solutions for developing sustainable smart cities.

Civil Societies

- 01 Educate Communities:**
Launch educational campaigns on sustainability practices such as energy conservation and e-waste reduction, as suggested by researchers in ^[118], to inform communities about the importance of developing sustainable smart cities.
- 02 Support Local Initiatives:**
Encourage grassroots efforts, such as community gardens, local recycling programs, and renewable cooperatives, as highlighted by researchers in ^[74], to strengthen local resilience in sustainable smart cities.
- 03 Report Greenwashing:**
Hold corporations accountable for misleading claims by leveraging media and public reports, as suggested by researchers in ^[115], to promote genuine sustainability in smart cities.

International Organizations

- 01 Global Standards:**
Establish benchmarks for energy efficiency, e-waste reduction, and green practices to guide smart cities worldwide toward common sustainability goals as suggested by practitioners in ^[119], to promote sustainable smart cities.
- 02 Cross-border Collaborations:**
Facilitate global collaboration and exchange of innovative practices for sustainable urban development through conferences and workshops, as recommended by researchers in ^[120], to enhance sustainability in smart cities.

These strategies inspire smart city stakeholders to mitigate environmental risks and ensure long-term resilience and sustainable growth in digitally driven smart city economies.



5. CRITICAL REFLECTIONS AND FUTURE DIRECTIONS

"Smart Cities in the Digital Age: A Roadmap for Ethical, Inclusive and Sustainable Urban Futures" offers a foundational understanding of the complexities inherent in smart city development, highlighting both its promise and its pitfalls.

However, a closer examination reveals areas ripe for further critical reflection and expanded research. One significant need lies in the development of robust evaluation frameworks (REFs). While the roadmap outlines aspirations for ethical, inclusive, and sustainable urban futures, concrete mechanisms for measuring progress and ensuring accountability remain less

defined. Future research must address this gap by establishing clear, measurable key performance indicators (KPIs) that extend beyond technological implementation to assess actual societal and environmental impacts.

The integration of existing and emerging smart city standards is paramount in developing these REFs. Organizations such as IFGICT, IEEE, and ITU offer valuable technical specifications and best practices that can inform the creation of these frameworks. Furthermore, aligning smart city evaluations with the United Nations Sustainable Development Goals (SDG UN

protocols) is crucial to ensure that urban development contributes to broader global sustainability objectives. This alignment would allow for a more holistic assessment of smart city initiatives, moving beyond purely technological metrics to encompass social equity, environmental stewardship, and economic viability.

Beyond technical and ethical evaluations, a critical dimension for future research involves the empowerment of citizens within the smart city paradigm. While the “Roadmap” alludes to the benefits of smart technologies for urban dwellers, deeper inquiry is needed into how these technologies can genuinely enhance citizen agency and participation.

This includes exploring novel approaches to participatory design processes, where residents are actively involved in shaping the smart city solutions that directly impact their lives. Research could investigate the

effectiveness of digital democracy initiatives, leveraging technology to facilitate greater civic engagement and decision-making.

Ultimately, the future trajectory of smart city research should prioritize community-led innovation. This involves examining tools and methodologies that enable residents to identify local challenges and co-create smart solutions, rather than being passive recipients of technology.

Such an approach would foster a more inclusive and democratic urban future, ensuring that smart cities truly serve the needs and aspirations of their inhabitants.

By focusing on robust evaluation, standard integration, and citizen empowerment, future research can build upon the “Roadmap’s” insights to forge urban environments that are not only technologically advanced but also profoundly ethical, inclusive, and sustainable.

CONCLUSION

This paper explores the interplay between digital technologies in smart cities and their role in fostering the digital economy while addressing critical challenges related to inclusivity, human-centered design, and sustainability. Technologies such as IoT, AI, and big data offer transformative opportunities to enhance urban operations, optimize resource management, and stimulate economic innovation.

However, their widespread adoption also introduces challenges, including the digital divide, algorithmic biases, data privacy concerns, energy inefficiencies, and environmental degradation. If left unaddressed, these issues could undermine the core objectives of smart cities improving quality of life and ensuring equitable economic growth.

This study stands out for its distinctive approach, as it not only identifies the challenges associated with digital technologies in smart cities but also classifies them into three key dimensions: inclusivity, humanity, and sustainability.

By connecting smart cities, digital technologies, and the digital economy, it provides a roadmap for addressing critical issues, including the digital divide, ethical dilemmas such as surveillance and data privacy, and environmental challenges like energy efficiency and e-waste management.



The study offers actionable, strategic recommendations for stakeholders, including policymakers, urban planners, businesses, and civil society to bridge disparities, uphold ethical standards, and adopt sustainable practices. Through collaborative efforts and ethical governance, smart cities can transform into equitable, human-centric, and environmentally resilient ecosystems, aligning with digital economy principles and paving the way for a sustainable urban future.

The study highlights key considerations that offer opportunities for further exploration. Future research should focus on developing a deeper understanding of specific technologies, such as AI-driven decision-making systems and IoT networks, impact inclusivity, human-centered design, and sustainability in smart cities.

Empirical studies that evaluate the long-term socioeconomic impacts of smart city projects across diverse regions, particularly in developing economies, are essential to ensure the global applicability of proposed solutions.

Additionally, exploring ethical frameworks to address emerging challenges, such as algorithmic governance and greenwashing in urban technologies, will be vital. Interdisciplinary approaches integrating environmental science, data ethics, and urban planning could help refine strategies to mitigate resource inefficiency and e-waste. Lastly, future studies should explore innovative business models that align economic incentives with sustainability goals, fostering smart cities that are both economically robust and socially equitable.

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We would like to express our sincere gratitude to the following authors and contributors for their invaluable input and collaboration in this work:

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ACKNOWLEDGEMENTS

Alaa Abdulaal

Chief of Digital Economy Intelligence (DEI),
DCO

Rashed Alsehaly

General Legal Counsel, Cabinet
DCO

Their expertise and dedication have significantly contributed to the successful completion of this paper.

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