

IntechOpen

IntechOpen Series
Sustainable Development, Volume 41

Smart Cities

Designing the Future of Urban Living

*Edited by Amjad Almusaed, Asaad Almssad,
Ibrahim Yitmen and Jonn Are Myhren*



Smart Cities - Designing the Future of Urban Living

*Edited by Amjad Almusaed,
Asaad Almssad, Ibrahim Yitmen
and Jonn Are Myhren*

Published in London, United Kingdom

Smart Cities – Designing the Future of Urban Living

<http://dx.doi.org/10.5772/intechopen.1008126>

Edited by Amjad Almusaed, Asaad Almssad, Ibrahim Yitmen and Jonn Are Myhren

Contributors

Ahmed Hassebo, Amjad Almusaed, Andrew D. Roberts, Asaad Almsaad, Bart Gorynski, Bessy Kathambi, Duha A. Jebur, Florence Ogutu, Ibrahim Yitmen, Jae Eun You, Safia Nahhas, Sudaff Mohammed, Zahraa M. Ibrahim

© The Editor(s) and the Author(s) 2025

The rights of the editor(s) and the author(s) have been asserted in accordance with the Copyright, Designs and Patents Act 1988. All rights to the book as a whole are reserved by INTECHOPEN LIMITED. The book as a whole (compilation) cannot be reproduced, distributed or used for commercial or non-commercial purposes without INTECHOPEN LIMITED's written permission. Enquiries concerning the use of the book should be directed to INTECHOPEN LIMITED rights and permissions department (permissions@intechopen.com)

Violations are liable to prosecution under the governing Copyright Law.



Individual chapters of this publication are distributed under the terms of the Creative Commons Attribution 4.0 License which permits commercial use, distribution and reproduction of the individual chapters, provided the original author(s) and source publication are appropriately acknowledged. If so indicated, certain images may not be included under the Creative Commons license. In such cases users will need to obtain permission from the license holder to reproduce the material. More details and guidelines concerning content reuse and adaptation can be found at <http://www.intechopen.com/copyright-policy.html>.

Notice

Statements and opinions expressed in the chapters are those of the individual contributors and not necessarily those of the editors or publisher. No responsibility is accepted for the accuracy of information contained in the published chapters. The publisher assumes no responsibility for any damage or injury to persons or property arising out of the use of any materials, instructions, methods or ideas contained in the book.

First published in London, United Kingdom, 2025 by IntechOpen

IntechOpen is the global imprint of INTECHOPEN LIMITED, registered in England and Wales, registration number: 11086078, 167-169 Great Portland Street, London, W1W 5PF, United Kingdom

For EU product safety concerns: IN TECH d.o.o., Prolaz Marije Krucifikse Kozulić 3, 51000 Rijeka, Croatia, info@intechopen.com or visit our website at intechopen.com.

British Library Cataloguing-in-Publication Data

A catalogue record for this book is available from the British Library

Smart Cities – Designing the Future of Urban Living

Edited by Amjad Almusaed, Asaad Almssad, Ibrahim Yitmen and Jonn Are Myhren

p. cm.

This title is part of the Sustainable Development Book Series, Volume 41

Topic: Urban Planning and Environmental Management

Series Editor: Usha Iyer-Raniga

Topic Editors: Rui Alexandre Castanho and Luís Loures

Print ISBN 978-0-85466-869-4

Online ISBN 978-0-85466-868-7

eBook (PDF) ISBN 978-0-85466-870-0

ISSN 2753-6580

If disposing of this product, please recycle the paper responsibly.

IntechOpen

intechopen.com

Built by scientists, for scientists



[Explore all IntechOpen books](#)

IntechOpen Book Series

Sustainable Development

Volume 41

Aims and Scope of the Series

Transforming our World: the 2030 Agenda for Sustainable Development endorsed by United Nations and 193 Member States, came into effect on Jan 1, 2016, to guide decision making and actions to the year 2030 and beyond. Central to this Agenda are 17 Goals, 169 associated targets and over 230 indicators that are reviewed annually. The vision envisaged in the implementation of the SDGs is centered on the five Ps: People, Planet, Prosperity, Peace and Partnership. This call for renewed focused efforts ensure we have a safe and healthy planet for current and future generations.

This Series focuses on covering research and applied research involving the five Ps through the following topics:

1. Sustainable Economy and Fair Society that relates to SDG 1 on No Poverty, SDG 2 on Zero Hunger, SDG 8 on Decent Work and Economic Growth, SDG 10 on Reduced Inequalities, SDG 12 on Responsible Consumption and Production, and SDG 17 Partnership for the Goals
2. Health and Wellbeing focusing on SDG 3 on Good Health and Wellbeing and SDG 6 on Clean Water and Sanitation
3. Inclusivity and Social Equality involving SDG 4 on Quality Education, SDG 5 on Gender Equality, and SDG 16 on Peace, Justice and Strong Institutions
4. Climate Change and Environmental Sustainability comprising SDG 13 on Climate Action, SDG 14 on Life Below Water, and SDG 15 on Life on Land
5. Urban Planning and Environmental Management embracing SDG 7 on Affordable Clean Energy, SDG 9 on Industry, Innovation and Infrastructure, and SDG 11 on Sustainable Cities and Communities.

The series also seeks to support the use of cross cutting SDGs, as many of the goals listed above, targets and indicators are all interconnected to impact our lives and the decisions we make on a daily basis, making them impossible to tie to a single topic.

Meet the Series Editor



Usha Iyer-Raniga is a professor in the School of Property and Construction Management at RMIT University. Usha co-leads the One Planet Network's Sustainable Buildings and Construction Programme (SBC), a United Nations 10 Year Framework of Programmes on Sustainable Consumption and Production (UN 10FYP SCP) aligned with Sustainable Development Goal 12. The work also directly impacts SDG 11 on Sustainable Cities and Communities. She completed her undergraduate degree as an architect before obtaining her Masters degree from Canada and her Doctorate in Australia. Usha has been a keynote speaker as well as an invited speaker at national and international conferences, seminars and workshops. Her teaching experience includes teaching in Asian countries. She has advised Austrade, APEC, national, state and local governments. She serves as a reviewer and a member of the scientific committee for national and international refereed journals and refereed conferences. She is on the editorial board for refereed journals and has worked on Special Issues. Usha has served and continues to serve on the Boards of several not-for-profit organisations and she has also served as panel judge for a number of awards including the Premiers Sustainability Award in Victoria and the International Green Gown Awards. Usha has published over 100 publications, including research and consulting reports. Her publications cover a wide range of scientific and technical research publications that include edited books, book chapters, refereed journals, refereed conference papers and reports for local, state and federal government clients. She has also produced podcasts for various organisations and participated in media interviews. She has received state, national and international funding worth over USD \$25 million. Usha has been awarded the Quarterly Franklin Membership by London Journals Press (UK). Her biography has been included in the Marquis Who's Who in the World® 2018, 2016 (33rd Edition), along with approximately 55,000 of the most accomplished men and women from around the world, including luminaries as U.N. Secretary-General Ban Ki-moon. In 2017, Usha was awarded the Marquis Who's Who Lifetime Achiever Award.

Meet the Volume Editors



Prof. Almusaed is an architectural scholar in environmental and sustainable design. He received his Ph.D. from Ion Mincu University of Architecture and Urbanism and completed postdoctoral research at Aarhus School of Architecture on bioclimatic housing. He is the author of five books, including *Biophilic and Bioclimatic Architecture* (Springer), and has published over 185 peer-reviewed papers. He has edited 20 scientific volumes and reviewed more than 400 articles for leading publishers, providing him with a comprehensive understanding of best practices and research gaps in sustainable architecture and urbanism. ORCID: <https://orcid.org/0000-0001-5814-2667>.



Prof. Almssad is Head of the Division of Building Technology at Karlstad University, Sweden. He teaches BIM-enabled design, concrete technology, and sustainable construction, and leads collaborations with industry and public stakeholders. His research focuses on smart materials, AI-integrated workflows, and climate-adaptive concrete systems, linking laboratory testing with digital twins and performance-based codes. He has supervised numerous theses and coordinates curriculum development in construction engineering. ORCID: <https://orcid.org/0000-0002-4536-9747>.



Prof. Yitmen has served at Jönköping University, Sweden, since 2018 and holds a Ph.D. in Architecture from Istanbul Technical University. His research advances digital innovation in the AEC industry, including digital twins, cognitive buildings, AR/MR, blockchain, and UAV-BIM integration. He has published over 140 peer-reviewed papers and edited books with CRC Press. He contributes to international committees such as CIB, ASCE, and EC3, shaping standards and knowledge in construction informatics and management. ORCID: <https://orcid.org/0000-0003-4288-9904>.



Jonn Are Myhren is Associate Professor of Building Technology at Dalarna University, Sweden. His research advances energy-efficient buildings, low-energy HVAC and ventilation control, sustainable renovation, and life-cycle assessment, with applications to energy-positive districts. He teaches building energy simulation, sustainable building rating systems, and low-energy HVAC, and has supervised graduate theses. Myhren leads externally funded projects supported by national agencies and collaborates with municipalities and industry to translate research into practice. He has authored numerous peer-reviewed publications and serves as a guest editor and reviewer in construction and energy engineering.

Contents

Preface	XV
Section 1	
Foundations, Governance, and Human-Centered Smart Urbanism	1
Chapter 1	3
Smart Cities That Think: Cognitive Infrastructures, AI Governance, and Sustainable Urban Futures <i>by Amjad Almusaed, Asaad Almsaad and Ibrahim Yitmen</i>	
Chapter 2	33
Smart City(ies) and Urban Living: The Paradox of the Good Life <i>by Andrew D. Roberts</i>	
Chapter 3	57
The Rise of the Smartivist: From Creative Class to Citizen-Centric Smart Sustainable Cities <i>by Bart Gorynski</i>	
Chapter 4	75
Smart Cities and Surveillance Technology: Balancing Innovation, Security, and Privacy in Urban Environments <i>by Ahmed Hassebo</i>	
Chapter 5	93
Harmonizing Smart Education in Smart Cities <i>by Safia Nahhas</i>	
Section 2	
Systems, Applications, and Regional Pathways	117
Chapter 6	119
Improving Energy Efficiency and Sustainability in Smart Cities <i>by Sudaff Mohammed, Duha A. Jebur and Zahraa M. Ibrahim</i>	

Chapter 7	145
Smart City Innovations in South Korea: Lessons for Emerging Economies	
<i>by Jae Eun You</i>	
Chapter 8	161
Missed Potentials of Recycling in Urban Planning: Case of East African Cities	
<i>by Ogotu Florence and Kathambi Bessy</i>	

Preface

Smart Cities – Designing the Future of Urban Living makes a strong case that “smartness” in cities is not just about having lots of gadgets; it is about using data and digital tools to make demonstrable changes in people’s lives. This edited book is meant for a wide range of readers, including municipal officials and practitioners, educators and students, community stakeholders and industrial partners, who want a brief, reliable introduction to the promises, constraints, and design conditions of modern smart urbanism. The introduction does not give any new scientific results. Its goal is to provide an overview of the book’s themes and structure, and to summarise the chapters that follow.

There are two sections in this volume. Section I, “Foundations, Governance, and Human-Centered Smart Urbanism”, lays the groundwork for judging “smart” projects by how they affect well-being, fairness, resilience, and trust. Section II, “Systems, Applications, and Regional Pathways”, takes these ideas and turns them into ways to put them into action in energy and materials systems, and into regionally based examples that show how choices about governance affect results.

Chapter 1: *Smart Cities That Think: Cognitive Infrastructures, AI Governance, and Sustainable Urban Futures* presents the city as a flexible information system. It discusses how sensor networks, interoperable data layers, and algorithmic services can support planning and operations in public spaces, buildings, energy, and mobility when they are part of a trustworthy governance system. Risk classification, determining the sources of data and models and how they may be checked, impact assessment for public purposes, and outcomes-based evaluation are all critical approaches. The chapter contends that standards and comparability, rather than customised innovation, are essential prerequisites for cumulative learning and intercity transfer.

Chapter 2: *Smart City(ies) and Urban Living: The Paradox of the Good Life* examines a fundamental tension: optimisation might yield efficiency while unintentionally diminishing comfort, autonomy, privacy, or social trust if it is narrowly conceived or inadequately regulated. The chapter proposes a multifaceted view of urban well-being encompassing health and environmental quality, personal safety and agency, cultural vitality, and inclusion. Then it gives standards for measuring digital interventions: not how advanced or extensive they are, but how much they improve these factors.

Chapter 3: *The Rise of the Smartivist: From Creative Class to Citizen-Centric Smart Sustainable Cities* sees the citizen as both a co-designer and a co-governor of digital public infrastructure. Participation is seen as a necessary part of the system, not just a way to make people feel good about themselves. Practical mechanisms include transparency clauses in procurement, opportunities for contestability and redress when automated decisions impact individuals’ lives, and funding for civic capacity

to enable communities to influence priorities, audit algorithms, and manage shared data. The chapter asserts that this civic shift is vital for legitimacy, quality, and enduring adaptation.

Chapter 4: *Smart Cities and Surveillance Technology: Balancing Innovation, Security, and Privacy in Urban Environments* deals with one of the most controversial areas of smart urbanism. It proposes a system that protects rights and is mindful of security risks by rejecting both naïve boosterism and blanket bans. This framework includes explicit purpose limitation, proportionality criteria, ex-ante impact assessments, algorithmic accountability, independent oversight, and practical appeal methods. The main idea is that safety and civil freedoms should be built into socio-technical systems from the start, with due process incorporated from the outset.

Chapter 5: *Harmonizing Smart Education in Smart Cities* looks at education as an essential part of city infrastructure. Connectivity and platforms are vital, but they are not enough; they need to work with pedagogy, accessibility, and lifelong learning to make people more capable and included. The chapter discusses how schools, libraries, workplaces, and public spaces can collaborate to create a citywide learning ecosystem. It also discusses teacher development, open educational resources, and public-facing data-literacy interfaces that make complex urban information easy to understand and use for everyone.

Section II — “*Systems, Applications, and Regional Pathways*” moves from planning to action.

Chapter 6: *Improving Energy Efficiency and Sustainability in Smart Cities* is a practical guide for making cities less carbon-intensive and more flexible on the demand side. It looks at building codes based on outcomes, large-scale retrofit plans, grid-compatible electrification, district energy solutions, and using open performance data to support buying and accountability. The throughline is institutional: multi-level governance, bankable contractual frameworks, and predictable revenue design are what turn technical potential into long-lasting, city-scale results.

Chapter 7: *Smart City Innovations in South Korea: Lessons for Emerging Economies* looks at how to coordinate policy, planning, and experimentation. The chapter extracts portable design rules, standards compliance, capability building, and iterative evaluation by examining district-scale “living labs,” regulatory sandboxes, and interoperable data platforms. The focus is not on copying artefacts, but on creating conditions that allow cities with limited resources to adapt solutions to their own needs while remaining accountable to the people.

Chapter 8: *Missed Potentials of Recycling in Urban Planning: Case of East African Cities* ends with a look at materials and systems. It rethinks waste management as a design problem that starts with product standards, source separation, collection logistics, market development, and the institutional recognition of the informal sector. The chapter demonstrates that enhanced data, focused infrastructure, and inclusive governance can facilitate employment, improve public health, and mitigate environmental impacts, therefore embedding circular-economy principles into routine urban administration.

We appreciate the authors of the chapters for their clear thinking and helpfulness, the reviewers for their constructive criticism, and our production team for preparing the work for publication. We are responsible for any flaws that remain. We also want to thank the many professionals and community partners whose everyday labour brings the practices on these pages to life.

Amjad Almusaed Ph.D.

Professor,
Department of Architectural Engineering,
The University of Basrah,
Basrah, Iraq

Asaad Almssad

Associate Professor,
Karlstad University,
Karlstad, Sweden

Ibrahim Yitmen Ph.D.

Professor,
Jönköping University,
Jönköping, Sweden

Dr. Jonn Are Myhren

Dalarna University,
Falun, Sweden

Section 1

Foundations, Governance, and Human-Centered Smart Urbanism

Chapter 1

Smart Cities That Think: Cognitive Infrastructures, AI Governance, and Sustainable Urban Futures

Amjad Almusaed, Asaad Almsaad and Ibrahim Yitmen

Abstract

This chapter presents the idea of “Smart Cities That Think” as a new way of looking at traditional innovative city models. It redefines urban intelligence as a mix of cognitive infrastructures, AI-driven governance, and citizen participation. The scope encompasses emerging technologies, like digital twins, context-aware systems, and predictive analytics, while also addressing participatory platforms and sustainability frameworks. The methodological approach is mainly conceptual and integrative, merging critical literature research with illustrative case studies from European and Asian cities. Three main discoveries come to light. First, digital twins and other predictive and adaptive technologies show measurable improvements in efficiency, such as less traffic and energy use in experimental programs. Second, citizen-centered models like participatory budgeting and open data projects make democracy more legitimate and build trust in society. Third, initiatives that focus on sustainability demonstrate that AI-driven systems can enhance resilience when used ethically. At the same time, ongoing problems like data privacy, algorithmic prejudice, and unequal governance show how dangerous it may be to depend too much on technology. The chapter concludes that thinking cities must balance technological innovation with ethical governance and citizen cooperation, creating a holistic pathway for resilient and inclusive urban futures.

Keywords: smart cities, urban intelligence, cognitive infrastructure, citizen participation, AI governance

1. Introduction

With more than two-thirds of the world’s population expected to reside in cities by 2050, the twenty-first century is witnessing unprecedented urbanization [1]. This type of urban growth presents significant opportunities and challenges, including regulating resource depletion, ensuring sustainable mobility, enhancing public safety, and addressing socioeconomic inequality. The concept of the smart city has become increasingly important as a significant paradigm in modern urban policy and development discussions. However, as Kunzmann points out, the term remains

conceptually unclear and open to various interpretations. Stakeholders who view its evolution as a means to enhance urban quality of life or as a platform to demonstrate their commitment to sustainable and efficient urban living have propelled it forward [2]. Simultaneously, the narrative of the smart city has been co-opted as a strategic term typically used to promote the development of information and communication technologies (ICTs) and market-related goods and services in the context of urban development [3].

Initially defined by applying digital and information technologies to enhance urban services and infrastructure, the smart city has evolved into a more complex and multifaceted concept encompassing cognitive capacity, ethical governance, and inclusive design. “Smart cities that think” encapsulates this new perspective. A thinking city goes beyond mere automation and digitalization. It integrates artificial intelligence (AI), the Internet of Things (IoT), big data analytics, and machine learning (ML) into the urban fabric to enable continuous sensing, comprehension, and adaptive decision-making. The urban environment gains the cognitive ability to envision future scenarios, optimize systems in real time, and coevolve with its inhabitants, moving beyond just being “smart” in data management. This represents a paradigm shift from efficiency-driven systems to context-aware, anticipatory infrastructures. For example, adaptive traffic control systems, energy grids featuring predictive load balancing, and AI-enhanced waste management are no longer futuristic concepts but current realities in cities like Singapore, Helsinki, and Amsterdam [4, 5].

Although research on smart cities has grown significantly in the past 10 years, there is still a substantial gap when it comes to integrated governance models that systematically bring together AI, IoT, public involvement, and sustainability. Current research often emphasizes either technology optimization or governance frameworks in isolation, which constrains the ability to conceptualize and implement urban systems as comprehensive and adaptive entities. This chapter aims to fill this gap by introducing the concept of “Smart Cities That Think.” The goal is to shift the conversation from automation and efficiency to cognitive systems that can learn, predict, and collaborate with residents to create urban futures that are strong, ethical, and inclusive. Crucially, a city’s intelligence is not limited to its technological capabilities; it is increasingly evaluated by its capacity to incorporate ethical considerations, foster civic engagement, and ensure equitable access to digital services. In this regard, thinking cities act as participatory ecosystems where residents are active stakeholders rather than passive data points, contrasting with top-down control systems. Supported by open data platforms, e-participation tools, and collaborative urban labs, the shift toward citizen-centered governance systems reflects a growing recognition that the social legitimacy of innovative technologies is vital to their effectiveness and sustainability [6]. Moreover, the future smart city must be ecologically adaptive and resilient. As climate change places increasing pressure on urban systems, it is essential to integrate real-time environmental monitoring, dynamic zoning regulations, and responsive urban design. Thus, cities must prioritize sustainability by reducing carbon emissions, enhancing biodiversity, and promoting a circular urban economy through data-informed design and smart governance [7]. Urban settings that use modern technology and intelligent systems capable of learning, adaptation, and proactive decision-making to improve city life are described as “smart cities that think.” These cities generate efficient and responsive urban ecosystems beyond simple automation, including artificial intelligence (AI), machine learning (ML), and data analytics. The basic components of “smart cities that think” are shown in **Figure 1**. The idea of intelligent urban systems sits at the center, backed by four interrelated

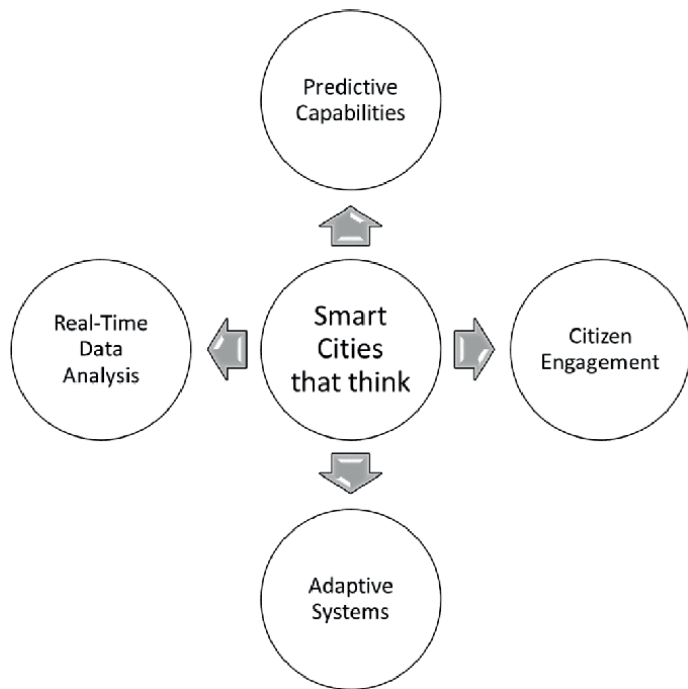


Figure 1.
Core components of thinking smart cities (Source: authors).

parts: real-time data processing, predictive capacities, adaptive systems, and citizen involvement. These components help cities dynamically react to problems, maximize resource use, and promote participatory government. The integration of these characteristics guarantees efficient and sustainable urban development that is propelled by data and creativity.

- *How do thinking cities extend beyond smart cities in the latest literature?*

Recent literature on smart cities underscores a shift from technology-driven automation to more comprehensive, human-centered, and adaptive frameworks of urban intelligence. Albino et al. (2015) and Batty et al. (2012) emphasize that initial conceptualizations were predominantly technical, concentrating on ICT infrastructures and efficiency improvements [4, 5]. Recent works, including Komninos et al. (2019) and Bibri (2018), emphasize evolutionary frameworks and the incorporation of big data analytics, context-aware computing, and sustainability into urban systems [8, 9]. In the same way, Caprari et al. (2022) and Ketzler et al. (2020) demonstrate how digital twins are transforming our predictive capabilities for cities using predictive and adaptive planning [10, 11]. Simultaneously, significant analyses by Green (2019) and Cardullo & Kitchin (2019) warn against technocratic government and the associated dangers of inequality, data dependency, and surveillance [12, 13]. This chapter situates itself at the convergence of these discussions by presenting the notion of “Smart Cities That Think,” which transcends mere automation and forecasting. The chapter shifts the conversation toward anticipatory infrastructures that combine technological innovation with democratic legitimacy, sustainability, and inclusivity by defining cities as cognitive, ethical, and participative systems. It enhances and contests current

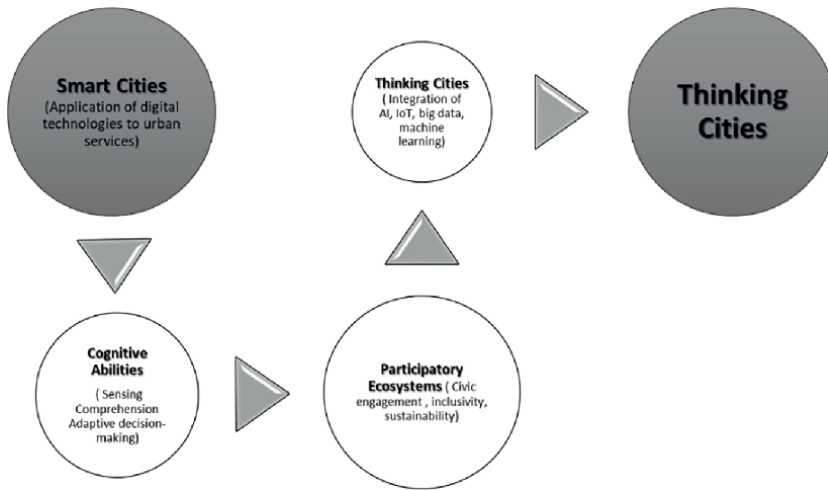


Figure 2.
From smart cities to thinking cities: A framework for intelligent and participatory urban systems (Source: authors).

literature by introducing an integrated paradigm that interlinks AI, IoT, and big data through citizen involvement, ethical governance, and adaptive resilience. While the concept of thinking smart cities is intriguing, it also raises significant concerns: data privacy, algorithmic bias, digital exclusion, and the potential corporatization of public spaces. These challenges necessitate an interdisciplinary, governance-sensitive approach to creative city development that combines technological innovation with normative frameworks rooted in justice, transparency, and democratic accountability. Through four interconnected lenses—technological infrastructure, urban cognition, citizen participation, and sustainable resilience—this chapter critically examines the emergence of “smart cities that think.” Analyzing the enabling technologies and sociopolitical structures that define the smart city paradigm offers a comprehensive view of how intelligent urbanism can shape the future of human settlements within a complex and rapidly evolving society [14]. From “Smart Cities” to “Thinking Cities,” **Figure 2** shows the conceptual shift. Smart cities are defined as using digital technologies to enhance urban amenities. This technological basis allows for the growth of cognitive skills like sensing, understanding, and adaptive decision-making. These qualities help to create participatory ecosystems, stressing civic involvement, inclusiveness, and sustainability. Eventually, the integration of modern technologies, including artificial intelligence (AI), the Internet of Things (IoT), big data, and machine learning, gives rise to thinking cities. This evolution reflects a change from data-driven administration to smart, citizen-centered, and morally conscious urban systems.

2. Method and material

This chapter employs an integrative literature review alongside a comparative case synthesis to formulate the “Smart Cities That Think” paradigm. The review identified four categories: AI/IoT technologies, governance, citizen participation, and sustainability. It used a transparent, repeatable process that included searching

databases (Scopus, Web of Science, and Google Scholar) with Boolean strings (for example, “smart city*” AND “digital twin*”; “context-aware” AND “urban”; and “AI” AND “governance”), screening by title/abstract, forward-backward snowballing, and a PRISMA-inspired flow to keep track of decisions about who to include. The time frame (2012–2025) shows when anticipatory urbanism started to grow. The inclusion criteria emphasized peer-reviewed studies, significant policy/standards reports, and books with clear urban consequences; merely technical works lacking governance significance were omitted. We classified the texts and experiences based on four areas: technical pillars, governance mechanisms, participation modalities, and methods for sustainability and resilience. We used a shared codebook and cross-case matrix in Excel to get the data, and we used Atlas to keep track of the qualitative memos. Indicators were normalized when necessary to make it easier to compare pilots. We then used pattern matching and replication logic on different implementations: Songdo (greenfield), Amsterdam and Singapore (retrofit), and Sidewalk Toronto (proposed/terminated). This was to test the linkage challenge → method → result (e.g., congestion → predictive control → measured reductions). Evidence was corroborated through academic sources and official program paperwork. The evaluation used both quantitative and qualitative measures, such as performance (traffic and energy outcomes), governance legitimacy (participation and transparency), ethical risk (privacy and bias), and scalability and transferability. The review is integrative (not systematic), with many types of indicators and a bias toward English. These risks are mitigated by using clear search strings, maintaining records of screening, triangulating from multiple sources, and being transparent about decision-making processes.

- *Results: Evidence from deployments*

Adaptive traffic lights in Pittsburgh lowered average travel times by almost 25%. At intersections with these lights, there was a clear drop in stopping and idling. Barcelona’s IoT-based park irrigation reduced the city’s water use by roughly 25% and lowered operating costs. The city’s LED streetlight retrofit in Los Angeles, which included smart controls, saved more than half of the energy used and cut costs by a significant amount each year. On the other hand, Toronto’s Quayside smart-district plan was put on hold due to concerns over privacy and data governance, highlighting the risks associated with legitimacy. These cases demonstrate the necessity of ethical governance for long-lasting change by connecting problems to effective solutions: congestion to adaptive control, resource waste to IoT optimization, and energy burden to smart retrofits.

3. Urban intelligence and the evolution of smart cities

3.1 Conceptual foundations and defining characteristics of the smart city

Over the past 20 years, the concept of a smart city has evolved from a simple term into a comprehensive approach for constructing, managing, and enjoying urban environments [12]. At its core, a smart city utilizes digital technologies not merely to upgrade infrastructure but to enhance urban life in a manner that is more efficient, sustainable, and responsive to the needs of its citizens. This idea signifies a shift from viewing cities as static, slow-moving entities to recognizing them as dynamic, interlinked networks capable of learning and adapting. A smart city integrates urban processes with digital technologies. For example, sensors and smart devices are

embedded in roadways, water systems, buildings, and public transportation to gather real-time data on ongoing activities [15]. Analyzing this data empowers city officials to make quicker and better decisions. Traffic signals can be adjusted automatically if congestion occurs at a particular spot. If a water line leaks, the system can detect it before it escalates into a significant issue. These are just a few practical examples of innovative technology enhancing everyday services. The cooperation of its systems is a key characteristic of a smart city; historically, transportation, electricity, healthcare, and waste services have operated independently. In contrast to traditional cities, smart cities prioritize integration. Energy systems, for example, can be connected to weather data to predict demand and reduce peak-hour usage. Transportation systems may be coordinated with emergency services to clear roads swiftly and improve accident response times. This level of collaboration saves time and money and preserves lives. Being a smart city encompasses more than just technology; it also involves centering the needs of people. Modern smart cities empower citizens to influence city operations actively. Apps, digital platforms, and online portals allow individuals to report issues, provide feedback, and even participate in designing public spaces [16]. This approach fosters trust between citizens and local governments and encourages a more democratic urban planning process. Individuals are more likely to engage in and support civic initiatives when they feel heard and valued. Another essential aspect of the brilliant city concept is sustainability. Cities become greener and more efficient through the use of technology. Smart grids, for instance, eliminate unnecessary energy consumption; intelligent waste management systems optimize collection routes, thus reducing emissions [17]. Real-time applications often connect public bike-sharing programs and electric transportation options, facilitating user-friendly, eco-friendly choices. Therefore, a smart city unites people, technology, and processes to enhance everyone's quality of life. It is about creating intelligent, inclusive, and prepared cities for the future, not solely about devices and data. **Table 1** emphasizes

Aspect	Definition	Application example	Outcome/Impact
Evolution of the concept	Shift from traditional to digital and interactive urban models over the past two decades.	Adoption of digital master plans in urban development	More adaptive and forward-looking city planning.
Core idea	Embedding digital tech in infrastructure and governance.	Use of AI in traffic systems and energy grids.	Improved efficiency, sustainability, and service quality.
Smart vs. traditional city	Traditional = centralized and physical; smart = dynamic, data-driven, and participatory.	Smart mobility apps vs. static public bus schedules.	Greater flexibility and real-time responsiveness.
Infrastructure and data	Use of IoT, sensors, and big data for monitoring and control.	Leak detection sensors in water networks and traffic light automation.	Reduced waste, faster service response, and proactive maintenance.
System integration	Interconnected services across various domains, including mobility, energy, and health.	Linking hospital emergency alerts with smart traffic systems.	Faster response and better coordination across departments.

Table 1.
Core dimensions of smart cities—integration, participation, and technological transformation.

the technological underpinnings, democratic frameworks, and systematic integration of six fundamental components of smart cities. It compares smart city dynamics with conventional urban models by emphasizing interoperability, data-driven decision-making, and public involvement. Through specific examples and essential results in twenty-first-century urban planning, the table shows how digital infrastructure and public involvement combine to provide more sustainable, efficient, and responsive urban settings.

3.2 The cognitive leap: From automation to prediction

3.2.1 From routine digitization to urban intelligence

The path of creative city growth shows a notable paradigm change: a trend from basic automation toward complete urban intelligence and awareness [18]. In its most basic form, the smart city idea was based on the digital transformation of routine and operational tasks under local government. This stage underlined the use of information and communication technologies (ICTs) to simplify public service delivery, lower manual effort, and improve efficiency in repetitive municipal activities. [19]. This basic stage includes electronic utility billing systems, digitizing payment processing and record-keeping, traffic signal management systems running on fixed schedules or simple sensor input, and automated street lighting systems reacting to daylight levels. These solutions eliminated resource waste, increased operational performance, and lowered human errors associated with manual processes. Though even if they worked well, these early inventions were small in scale. Their primary purpose was reactive, responding to events after they happened instead of anticipating or stopping them. **Figure 3** shows the gradual evolution of smart cities from simple digital automation to a basis able to sustain predictive and adaptive intelligence. Starting with regular ICT projects meant for efficiency, it moves on to piecemeal system operations and reactive responses. The last stage emphasizes the creation of integrated infrastructures and data ecosystems, readying cities for context-aware, proactive urban government driven by artificial intelligence and real-time analytics.

A traffic camera, for example, could monitor accidents or congestion in real time, but human interpretation of the data still governs choices on sending emergency services or rerouting traffic [20]. Therefore, humans' speed and capacity frequently limit technology's value. Moreover, this stage lacked the cross-sectoral coordination and integration required for complete urban administration. Systems mostly ran in silos; transportation, energy, garbage, and public safety systems operated separately, collecting data but seldom interacting across sectors—fragmentation like this hampered cities' capacity to create a coherent, data-informed knowledge of their rich dynamics. Laying the technological basis for more intelligent systems, the early digitization era provided a vital foundation. It brought the platforms, sensors, and tools required for automation and



Figure 3.
Evolutionary stages from routine digitization to urban intelligence (Source: authors).

data collection. Still, it did not give the cities the analytical intelligence needed to make informed decisions based on changing trends, contextual factors, or predictive foresight [21]. Eventually, this constraint spurred the next stage of evolution: the move to cognitive urbanism, in which sophisticated computational models allow data to be not only gathered but also analyzed, learned from, and acted upon autonomously.

3.2.2 The emergence of predictive urbanism

Today's smart cities are evolving from only about automation to smart systems capable of learning, forecasting, and real-time action [22]. Cities are entering a new era, sometimes called predictive urbanism, because of technology such as artificial intelligence (AI), machine learning, and big data analytics. This phase is about more than just reacting to present events. It is about anticipating what could come next and preparing for it ahead of time. This change enables cities to analyze data, identify trends, predict future events, and make more informed judgments without the need for continuous human direction, beyond merely gathering data. The aim is to create urban spaces that are proactive, flexible, and able to self-improve as well as efficient. Predictive policing is one strong illustration. AI systems can assist in identifying areas where crimes are more likely to occur by using historical crime records, local behavior patterns, and geographic data. This enables police forces to use their resources more strategically, hoping to avoid issues before they occur. In medicine, this knowledge can be life-changing [23]. Wearable technologies such as health monitors and smartwatches can now track heart rate, sleep, and oxygen levels. These devices provide real-time data to centralized health systems, where software can follow developing public health trends or identify early signs of disease. This early warning system often enables health providers and physicians to intervene before someone knows something is wrong. Predictive urbanism, however, is not only about crime and health. It also aids in controlling energy use, traffic patterns, and emergency response. Smart energy systems, for instance, can forecast when demand will rise and change distribution to prevent blackouts. Traffic systems can recommend quicker routes and forecast congestion before it develops. By enabling cities to react fast and safeguard their people, weather forecasting tools can examine data to alert them to approaching storms or heat waves. Simply put, cities are beginning to plan. They are learning to recognize their patterns, change in real time, and grow from experience. Predictive urbanism is not just for governments and planners but also for the everyday people who live in these cities. It is about making urban living smoother, safer, and more sustainable [11]. This change is not just an idea; AI-based traffic forecasting and predictive policing have been used in Singapore and New York, where they have shown real results, including a 20% drop in traffic congestion and earlier detection of public health threats. These tested results make the proposed fixes for isolated, reactive systems stronger. A simplified view of how predictive urbanism operates in current smart cities is shown in **Figure 4**. Data input from several sources initiates the process, followed by analytical processing that highlights trends and patterns. Then, predictive models project possible results that guide systems of decision-making. These choices result in real-time urban activities, producing a responsive and adaptive city that meets needs and continuously improves performance.

3.2.3 The role of digital twins in urban forecasting

The creation and use of digital twin technology, a complex digital representation of a physical urban system running in near real-time, is a significant turning

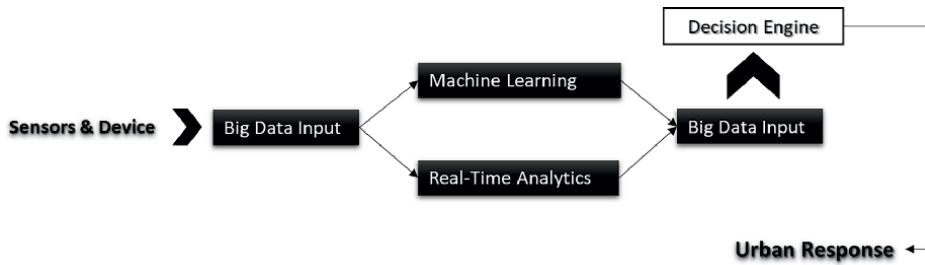


Figure 4.
 Simplified operational flow of predictive urbanism (Source: authors).

point in the evolution of smart and cognitive cities [9]. Digital twins provide a dynamic and interactive model that reflects the city's physical, environmental, and infrastructural circumstances by combining data from many sensors, systems, and urban assets. Unlike conventional simulation tools, digital twins offer a constantly updated, context-aware environment that enables predictive analysis and real-time monitoring. Digital twins are strategic tools in modern urban management that predict the results of suggested changes [13]. These models let planners, politicians, and engineers assess the effects of choices before they are physically carried out by allowing thorough simulations spanning sectors like traffic systems, energy distribution networks, land use, and environmental impact. This predictive ability is beneficial in reducing expensive mistakes, allocating resources more effectively, and enhancing the responsiveness of urban systems to changing demands and outside pressures. A digital twin, for instance, can simulate passenger distribution, peak-hour congestion, modal split changes, and expected emissions when considering adding a new public transportation route [24]. The simulated environment can also consider general urban dynamics like land use relationships, socioeconomic habits, and energy needs. Using these combined studies, decision-makers can evaluate the trade-offs between different situations, guaranteeing that the chosen path of action fits more general goals, including sustainability, equity, and resilience. Digital twins also let policies be tested iteratively. Urban planners can create and evaluate several design options or policy frameworks in a risk-free virtual environment. This enables cities to move from reactive governance to evidence-based, anticipatory planning, where future issues can be investigated and addressed before they materialize. Digital twins' flexibility also promotes ongoing improvement: the model changes to provide more accurate insights over time as fresh data is added to the system [25]. **Figure 5** shows the related areas supporting the use of digital twin technology in urban forecasting. Functional areas, including traffic management, energy modeling, and environmental evaluation, are connected to core components such as real-time monitoring, predictive simulation, and decision support. With more accuracy and robustness, this integrated system improves cities' ability to plan proactively, assess public effects, and carry out informed, data-driven municipal policies.

Digital twins are a vital infrastructural component of the predictive urban paradigm, closing the gap between static planning and dynamic, data-informed urban governance by equipping cities with the means to navigate complexity, ambiguity, and rapid transformation [26]. Digital twin technology enables informed, open, and resilient urban decision-making as cities strive to become more intelligent, sustainable, and citizen-centric.

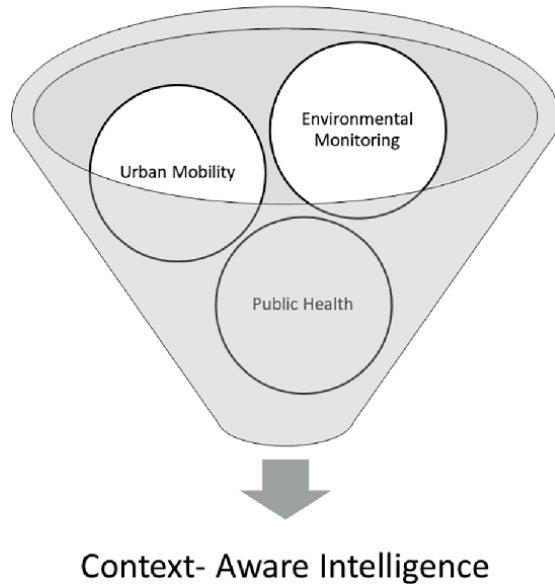


Figure 5.
Interdisciplinary system of digital twin applications in urban forecasting.

3.2.4 Context-awareness and adaptive learning

One of the most essential features of the developing cognitive city paradigm is context-awareness, the ability of urban systems to read and act on data within a larger situational framework, including environmental, cultural, temporal, and behavioral factors [27]. Unlike traditional automated systems that react to predetermined triggers or static thresholds, context-aware systems evaluate the meaning and usefulness of data concerning the particular circumstances in which it is produced [28]. This development signals a move from deterministic programming toward more intelligent, responsive, and situationally adaptive systems. Context-awareness enables smart infrastructure to transition from reactive operation to anticipatory control. An intelligent energy system, for example, does not just change depending on real-time changes in electricity use [29]. Instead, it forecasts demand and optimizes energy distribution using seasonal weather patterns, building occupancy trends, time-of-day consumption profiles, and dynamic pricing structures. This integration guarantees supply-side efficiency and demand-side responsiveness, improving sustainability, lowering operating costs, and increasing end-user happiness. Besides energy systems, context-aware intelligence may be integrated into public health infrastructures, environmental monitoring networks, and urban transportation platforms [30]. For instance, a transportation management system can change traffic signals depending on vehicle volume and consider weather conditions, special events, or pedestrian density, improving safety and flow efficiency. Likewise, air quality monitors could activate adaptive ventilation plans in public buildings if outdoor pollution levels surpass thresholds pertinent to vulnerable populations, such as children or older people [31]. Case studies in Helsinki and Barcelona demonstrate that context-aware energy modeling decreases peak loads by 15% and enhances transportation efficiency, establishing a direct correlation between the methodological approach and outcomes that address inefficiency and resource wastage. Urban mobility, environmental monitoring, and public health are three critical areas where

context-aware intelligence improves urban utility, as shown in **Figure 6**. By combining real-time data with situational awareness, cities may dynamically change to fit evolving circumstances. Health safeguards for at-risk groups, pollution-responsive ventilation systems, and adaptive traffic control are included. Together, these features help to create more intelligent, safer, and more responsive urban spaces that align with the ideas of cognitive urbanism.

This movement toward adaptive learning signifies a more profound shift in cities' interactions with complexity and unpredictability. Urban systems are being progressively built to learn from past data, adapt to changing trends, and improve their reactions without clear reprogramming [32]. Through constant contact with their surroundings and users, these systems develop what can be termed urban intelligence—a capacity for self-calibration based on new information, abnormalities, and contextual signals. The result is the rise of self-optimizing cities, urban ecosystems able to dynamically allocate resources in reaction to changing demands, minimize risks, and lower disturbances. Cities may increase functional performance and strengthen their residents' resilience, inclusiveness, and quality of life by including adaptive learning into their operations [33].

3.3 Technological pillars and global implementations

A strong and interdependent technical infrastructure, comprising several fundamental pillars that work in harmony, supports the development and operationalization of smart cities [34]. These elements help cities move from reactive government to proactive, smart urban systems. Among the most important are artificial intelligence (AI), the Internet of Things (IoT), big data analytics, 5G connectivity, and edge computing. Together, these technologies form the foundation for adaptive urban management, real-time monitoring, and evidence-based decision-making spanning

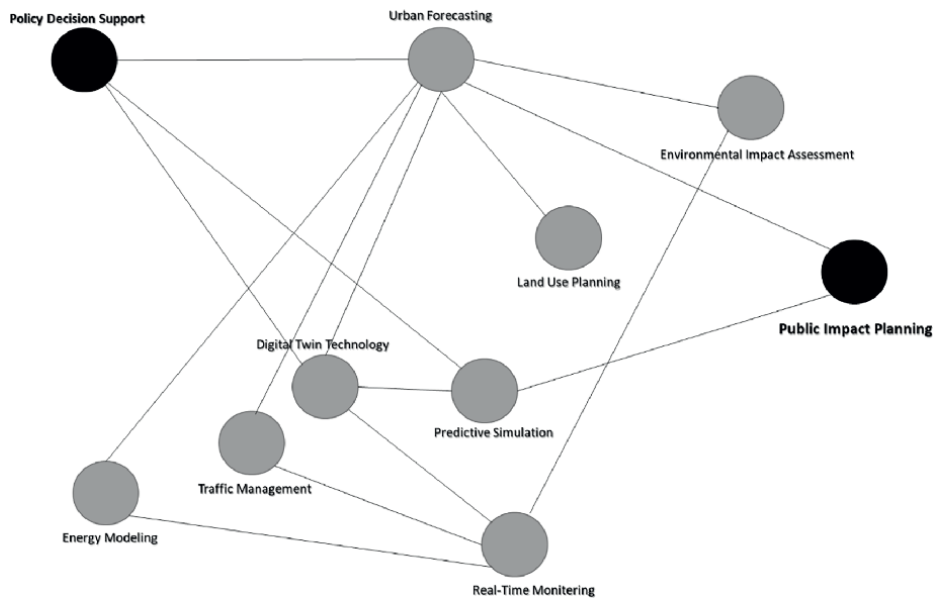


Figure 6.
Functional applications of context-aware intelligence in urban systems.

mobility, energy, public safety, and environmental management. Smart cities can react dynamically to changing circumstances, forecast demands, and maximize resources using constant data flows and automated processing. The technological and strategic challenges of successfully integrating these pillars necessitate careful governance, cybersecurity protections, and citizen confidence. Despite worldwide urban concerns, this all-encompassing technical basis enables cities to be more resilient, inclusive, and sustainable.

3.3.1 Core technological pillars

- Artificial intelligence

Artificial intelligence, sometimes called the “cognitive core” of the smart city, is at the center of smart urban systems [35]. Without direct human involvement, artificial intelligence enables computers and robots to automatically examine large datasets, learn from trends, and make informed decisions. Its uses vary from deep learning techniques for dynamic traffic signal optimization to natural language processing in automated public service chatbots. AI enables predictive analytics, anomaly detection, and behavioral forecasting, vital for responsive, scalable, citizen-centered government.

- Internet of Things

Smart cities’ sensory infrastructure is built on the Internet of Things (IoT). The IoT ecosystem enables ongoing, bi-directional data exchange between physical objects and digital platforms through the implantation of sensors and connection modules in urban assets, including streetlights, waste bins, busses, and water systems [36]. This connectivity enables real-time monitoring of mobility systems, infrastructure health, environmental conditions, and public safety. Applications such as smart parking, flood detection, and intelligent energy metering contribute to operational efficiency and an improved quality of life.

- Big data and data analysis

Smart cities produce vast amounts of organized and unstructured data across several sectors. Big data systems must store and manage this information, extracting valuable insights through advanced analytics. By identifying trends, inefficiencies, and correlations across various datasets, city officials can make evidence-based decisions that improve public policy, maximize services, and support urban equity [37]. Moreover, data-driven innovation enables cooperation between government, business, and academic institutions.

- 5G connectivity

5G network rollout is a transforming facilitator of innovative city features. 5G enables vital applications needing real-time responsiveness using its tremendous bandwidth, ultralow latency, and capacity to link numerous devices concurrently. Among these are remote healthcare delivery, high-definition surveillance, augmented reality interfaces, and driverless cars. Furthermore, 5G improves the robustness of the communication infrastructure and enables the smooth operation of thick IoT ecosystems [38].

- Edge computing

Edge computing brings data processing nearer to the data source to solve the latency and security concerns of centralized computing. Edge computing improves data privacy, saves bandwidth, and lowers delays by running computation at the network’s “edge” within sensors, gateways, or local servers [39]. Time-sensitive applications like autonomous drone navigation, emergency response systems, and smart surveillance make this especially important.

Including artificial intelligence, the Internet of Things, big data analytics, 5G connectivity, and edge computing, **Figure 7** illustrates the fundamental technological cornerstones necessary for realizing smart cities. These technologies, when combined, enable evidence-based decision-making, real-time monitoring, and adaptive urban management. Their integration creates a flexible and scalable system that enhances urban resilience, efficiency, and sustainability in the face of dynamic and complex metropolitan challenges.

3.3.2 Global implementations and case studies

Many cities across the globe have become leaders in the use of smart technologies, hence highlighting a great range of methods suited to their particular sociopolitical, environmental, and infrastructural settings [40]. Some cities have adopted top-down, government-led policies, while others have emphasized public-private partnerships or community-driven innovation. Each implementation is also significantly shaped by the degree of technology preparedness, legal frameworks, and cultural acceptability of digital solutions. These case studies offer insightful analysis of scalable methods for smart, sustainable urban futures, whether *via* greenfield projects like Songdo in South Korea or retrofit efforts like those in Amsterdam and Singapore.

- Songdo, South Korea

Built as a planned smart city, Songdo is a prototype of greenfield creativity. The town features integrated command centers, universal sensor networks, pneumatic garbage collection systems, and extensive broadband infrastructure [41]. Its design

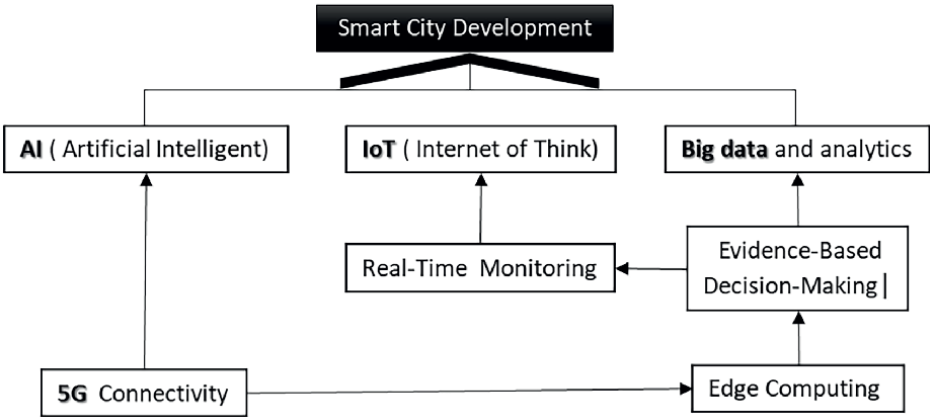


Figure 7.
Integrated technological framework enabling smart city development.

exhibits a high degree of centralization and automation, providing insight into the potential of a purpose-built digital metropolis.

- Amsterdam, The Netherlands

The city emphasizes embedding smart solutions into the current urban fabric as part of the “Amsterdam Smart City” project. Projects include smart mobility, energy efficiency, digital involvement, and climate resilience [42]. Pilot projects demonstrate how small innovations can yield scalable results using household smart grids, real-time energy use dashboards, and canal monitoring systems equipped with embedded sensors.

- Singapore

Through its ambitious “Smart Nation” initiative, Singapore leads the world in smart city governance. Its holistic approach includes e-government services, urban planning *via* digital twins, AI-enhanced traffic systems, and individualized digital identity platforms [43]. Projects such as MyInfo and predictive health analytics underscore the government’s commitment to seamless digital interaction and anticipatory public services.

- Toronto’s Sidewalk Labs (Canada)

Although the Sidewalk Toronto initiative was ultimately shelved, it remains a remarkable case of ambitious, innovative urban planning driven by private-sector creativity [44]. The plan envisioned a data-intensive, AI-powered neighborhood that emphasized modular construction, dynamic zoning, and integrated sustainability elements. Although people voiced concerns about data privacy and governance, the initiative sparked significant debate on the ethical deployment of urban technology and the role of corporate actors in civic space.

3.3.3 Comparative reflections

These instances show the variety of methods in smart city growth. Cities like Songdo are greenfield models, meaning their infrastructure is built from the ground up with digital integration in mind. On the other hand, cities like Amsterdam and Singapore pursue retrofit designs, stacking smart technologies on top of current urban infrastructure [45]. Although there are many approaches to execution, every case study shows a common will to use digital innovation in the quest for livability, sustainability, and resilience. Smart cities’ technology basis is a flexible framework rather than a one-size-fits-all answer; it has to be customized for the social, environmental, and institutional circumstances of any metropolitan setting. The function of these technological foundations will become increasingly crucial in shaping the future of human settlements as global urbanization accelerates and cities confront complex challenges such as social inequity, resource depletion, and climate change. A comparison of four worldwide smart city projects in **Table 2** shows their implementation methodologies, fundamental technological techniques, and unique qualities. The examples range from renovated urban systems like Amsterdam and Singapore to new projects like Songdo and Sidewalk Toronto. These instances show several routes for including digital infrastructure into urban planning, governance, and sustainability practices in different sociopolitical and technological settings.

City	Type of initiative	Main strategies	Notable features
Songdo, South Korea	Greenfield development	Centralized control centers, pneumatic waste, sensor networks, and broadband access	High automation, planned from scratch as a digital urban prototype
Amsterdam, Netherlands	Retrofit of existing infrastructure	Smart mobility, energy efficiency, citizen participation, and sensor-based monitoring	Real-time dashboards, smart canal systems, and strong civic integration
Singapore	Retrofit of existing infrastructure	E-government, digital twins, AI traffic systems, and citizen data services	Holistic “Smart Nation” model, predictive healthcare, and seamless digital governance
Toronto (Sidewalk Labs)	Proposed greenfield development	AI-based design, modular housing, sustainability, and dynamic zoning	Discontinued but sparked global debate on data ethics and corporate urban planning

Table 2.
Comparative overview of global smart city implementations.

3.4 Thinking infrastructure: Cognitive technologies in the urban fabric

Urban infrastructure is becoming intelligent, adaptive, and context-aware rather than just a passive backdrop to everyday life [46]. A silent revolution is happening as cities become complicated, linked ecosystems: infrastructure itself is beginning to “think.” Cognitive technologies, especially artificial intelligence (AI), machine learning (ML), sensor networks, and the integration of edge computing, drive this change. Unlike conventional systems that run on set routines and human supervision, cognitive urban infrastructure can sense, process, learn, and act in real time. For example, artificial intelligence algorithms built into transportation systems can examine real-time traffic patterns, forecast congestion, and automatically change signals to enhance flow. Likewise, water management systems with sensors can detect leaks, monitor quality, and trigger automatic repairs or alarms to prevent problems from escalating. Fundamentally, this new wave of thinking infrastructure is transforming city functioning [47]. It enables people to foresee demands, maximize resources, and respond to environmental, social, or technical issues with agility and intelligence. Practically speaking, this implies public areas that change lighting and temperature to improve comfort and safety, trash systems that alert collection teams when full, and streetlights that dim when no pedestrians are close. The following sections delve into the specifics of how cognitive technologies are being integrated into basic city services, urban sensing systems, and environmental control systems. This integration is not only increasing operational efficiency but also rethinking the urban experience itself, making cities more responsive, sustainable, and human-centered. Cognitive technologies, AI, machine learning, sensor networks, and edge computing are shown in **Figure 8** as key components changing conventional urban infrastructure into smart, adaptive systems. Across industries like transportation, water management, and public services, these technologies provide real-time sensing, learning, and autonomous action. The picture highlights how this integration enhances urban efficiency, responsiveness, and sustainability, thereby transforming how cities operate and engage with their residents.



Figure 8.
Cognitive technology integration in urban infrastructure (Source: authors).

3.4.1 Cognitive engines: AI and machine learning in urban operations

Urban infrastructure is changing profoundly. Today's cities are increasingly shaped by artificial intelligence (AI) and machine learning (ML) rather than by established norms and human monitoring [48]. These technologies are the “cognitive engines” of modern urban environments, allowing systems to learn from data, adapt to real-world conditions, and make intelligent decisions in real time. Traffic control is a clear illustration. Historically, traffic lights operated on set timers, disregarding real-time congestion or unanticipated incidents. AI enables urban traffic systems to optimize traffic flow using real-time data analysis from road sensors, cameras, and GPS devices. Lights change depending on weather conditions, car density, and pedestrian movement [49]. Avoiding needless idling and congestion helps to cut delays as well as emissions. AI is being applied in predictive policing in public safety. Algorithms anticipate where events are most likely to happen by processing previous crime data, social and environmental factors, and real-time inputs. This enables more effective resource allocation by law enforcement. Although such systems raise ethical questions about surveillance and prejudice, they reveal a broader trend: integrating intelligence into city security systems. AI has even changed how we think about waste management. Smart bins notify garbage collection providers using fill-level sensors when they require emptying. ML models then identify the most efficient collecting paths, hence reducing operational expenses and fuel consumption. AI-powered cameras and robots at recycling centers can now autonomously sort and identify waste, thus increasing recycling rates and lowering pollution. These instances draw attention to a common idea: urban systems are dynamic. They study, grow, and change the city into a constantly evolving organism that fits its people and their behavior.

3.4.2 Sensing the city: Sensor networks and digital twins

The ability to sense and perceive is at the core of cognitive cities. Like a nervous system tracking air quality, traffic, water use, noise levels, structural stress, and more, cities have a thorough and ongoing awareness of their surroundings using ubiquitous sensor deployment [50]. Often linked together *via* digital twins, virtual representations of the physical city continuously updated with real-time data, these sensors provide a live, dynamic simulation of urban situations, unlike conventional urban models that call for manual updates. Urban planners might use them to evaluate situations: for example, assess the wind patterns and shading of a suggested high-rise building before construction, or simulate how a flood might affect emergency response and traffic flow. Apart from simulations, sensors are directly embedded into infrastructure. Smart thermostats track indoor temperatures and change heating

or cooling automatically. Monitors of air quality guide choices on traffic controls in contaminated areas. Innovative public transportation systems adjust timetables based on sensor measurements of passenger loads. Even roads and bridges can notify engineers of unusual vibrations or stress, hence enabling accident prevention before they occur. Essentially, the constructed world gets self-aware. Infrastructure is no longer passive; it knows its state, its function, and its influence. Greater safety, efficiency, and sustainability follow from this improved awareness. A lamppost could pick up increasing noise levels [51]. A park bench could indicate damage from the weather. These constant, minute changes help cities to respond more quickly to both regular demands and exceptional occurrences and enable them to make better choices.

3.4.3 Intelligent elements: Edge AI in infrastructure and environment

Although cloud computing has long fueled the digital capabilities of smart cities, a new change is happening: intelligence is migrating to the edge [52]. Edge AI delivers processing power straight to the source of data: sensors, gadgets, and systems integrated into the urban environment. This translates to quicker decisions, reduced reliance on central data centers, and enhanced privacy protection. A convincing case is the clever streetlight. Today's lampposts are more than simply a light source; they can come with environmental sensors, cameras, and edge processors. All without having to transmit data to a central hub, these systems can monitor air quality, detect motion, change light depending on pedestrian activity, and even spot noise issues or unlawful dumping. This increases real-time responsiveness and lowers bandwidth consumption. Edge artificial intelligence in smart buildings maintains interior air quality, monitors occupancy, and tracks energy utilization. These systems change ventilation, temperature, and lighting depending on human activity and weather conditions. Over time, they learn trends and optimize resource utilization, hence significantly lowering energy use and enhancing occupant comfort. They also help systems of urban transportation. Trains and busses equipped with edge processors can interact with other network cars, notify control centers, and identify mechanical issues [53]. At stations, crowd-monitoring artificial intelligence can change platform displays or announcements based on real-time occupancy. Edge artificial intelligence has significant environmental effects as well. Smart grids employ embedded intelligence in local devices such as solar panels, storage batteries, and EV chargers to balance energy demand and supply. These systems, which dynamically allocate resources and predict peak loads, communicate with one another. This distributed approach not only increases efficiency but also strengthens outage resistance and lessens environmental impact. Edge AI is becoming more critical for catastrophe resilience. Sensors in flood-prone regions can identify increasing water levels and automatically activate protective barriers. Smart towers fitted with visual artificial intelligence technologies can detect smoke in wildfire areas and notify rescue services in seconds. These instances taken together illustrate how edge artificial intelligence transforms infrastructure into an independent, intelligent agent. Cognition is spread over the urban environment faster, more securely, and locally optimized rather than relying just on central command centers. A comparison of how different cognitive technologies, AI, sensor networks, and edge computing are incorporated into urban infrastructure to produce smart, responsive cities is shown in **Table 3**. Ranging from adaptive traffic control and predictive policing to smart waste systems and disaster-resilient buildings, each focal area emphasizes particular technologies and their practical applications. Urban advantages include improved sustainability, operational efficiency, and real-time

Focus area	Key technologies	Main applications	Urban benefits
AI and machine learning in cities	AI, machine learning	Traffic control, predictive policing, and smart waste management	Real-time decision-making, reduced emissions, and optimized resource allocation
Sensor networks and digital twins	Sensor networks, digital twins	Urban simulation, air quality control, and infrastructure monitoring	Continuous awareness, better planning, and proactive maintenance
Edge AI in infrastructure	Edge AI, edge computing	Smart lighting, smart buildings, disaster resilience, and transportation	Faster responses, energy efficiency, increased safety, and sustainability

Table 3.
Functional domains of cognitive technologies in urban infrastructure.

decision-making. Cities evolve from reactive systems into proactive ecosystems that continually learn and adapt to meet human and environmental needs with precision and agility, incorporating intelligence directly into the built environment.

4. In citizen-centric design: Individuals as co-creators of the smart city

4.1 Practicing participation: Citizen engagement platforms

The citizens' involvement in modern urban governance is changing from passive service recipients to active participants in city building [54]. This development shows a more general movement toward inclusive, citizen-centric planning models in which personal and group contributions are included in urban innovation initiatives and decision-making processes. Participatory digital platforms primarily drive this change. Mobile apps provide direct communication lines between citizens and city governments, hence allowing the reporting of problems, including infrastructure damage, environmental disruptions, and public safety concerns. These instruments help the local government to be more responsive and responsible. Some cities use participatory budgeting techniques whereby residents may affect the distribution of public money for community initiatives. By matching spending with locally stated priorities, such systems increase the legitimacy of policy decisions, encourage openness, and support democratic principles. Enabling citizen involvement is also significantly aided by open data portals. Public access to datasets spanning sectors such as environmental conditions, transportation flows, and urban services lets people and businesses examine data, spot problems, and create data-driven solutions [55]. This transparency fosters localized problem-solving, informed decision-making, and creativity. Urban hackathons show the cooperative power of digital civic spaces. Time-bound events like these bring together diverse attendees, including designers, engineers, students, and policy experts, to co-develop solutions for urban issues. Outputs usually consist of spatial planning tools meant to meet particular community requirements, technical applications, or prototypes of public services. The spread of readily available digital platforms has helped to democratize urban development procedures. Citizens are affecting the priorities of municipal programs, providing ideas, and guiding the design and delivery of public services. Spatial planning methods like the Ten-Minute City and One-Minute City have surfaced in Sweden as viable examples of

citizen-centric urban design. Pilot projects in cities like Gothenburg demonstrate the Ten-Minute City concept, which emphasizes the importance of making essential amenities, such as schools, parks, stores, and healthcare, accessible within a ten-minute walk or bike ride from residential areas [56]. Developed in Stockholm, the One-Minute City emphasizes the hyper-local reactivation of public space by transforming underutilized locations like parking lots into community centers for relaxing, chatting, and spontaneous engagement. These designs reflect the values of accessibility, proximity, and community-driven urbanism, while also enhancing daily quality of life. Smart city projects are advancing, and the institutionalization of participatory processes and proximity-based planning is being increasingly acknowledged as vital for the development of fair, inclusive, and strong urban systems. Pilot initiatives, such as participatory budgeting in Gothenburg and open data hackathons in Amsterdam, demonstrate that these methods effectively increase public trust in the government and ensure that resources are shared fairly. This turns participation from a theory into a proven way to run a government. The linked elements of citizen-centric urban governance are shown in **Figure 9**. Participatory tools, including mobile apps, open data portals, participatory budgeting, and hackathons, all facilitating active civic involvement, are central to the paradigm. It also draws attention to spatial planning developments, including the One-Minute City and Ten-Minute City, which support proximity-based accessibility. These components taken together help to create smart cities that are inclusive, responsive, and cooperative.

4.2 Equity in the digital age: Bridging divides and ensuring access

The promise of innovation is coupled with an essential question: Who gets to participate in the smart city as cities transform into digitally connected environments? Although digital tools can connect, inform, and empower, not everyone is on



Figure 9.
Citizen-centric design and participatory mechanisms in smart cities (Source: authors).

equal ground in this evolution [57]. Without careful policies to guarantee fair access and involvement, the rapid pace of technological change could exacerbate current inequities. The digital gap goes beyond simply owning a smartphone or having an online connection. It encompasses the capacity to participate boldly and competently in a society where digital literacy progressively affects services, communication, and possibilities. For many, especially older people, low-income families, migrant communities, and those with disabilities, there are systemic barriers restricting access to the advantages of digital city life. In a smart city that relies on automated kiosks for communication, websites for public services, and apps for transportation, these disparities risk becoming obstacles to necessary services. Urban projects are being designed with equity at their center to meet these difficulties. Public places like libraries, parks, and transit stops are being outfitted with free internet access to benefit people without a home connection. In certain areas, local governments are helping community centers with initiatives that lend gadgets or provide digital training, therefore empowering individuals to negotiate online systems with more confidence and autonomy. Another vital aspect is accessibility. Digital platforms have to be designed to benefit people with different abilities, including those with visual, auditory, cognitive, or mobility limitations. This calls for carefully designed interfaces compatible with screen readers, voice command-responsive buttons, and uncluttered, non-overloading layouts. An inclusive platform welcomes variety from the beginning rather than assuming one user profile. Another door to inclusion is language. Lack of language assistance in multilingual and multicultural areas can cause loneliness. Smart city tools and interfaces are becoming increasingly flexible, offering translations and cultural adaptations to ensure all citizens can effectively access digital services. In the digital era, equity is not only about technical solutions [58]. It is about acknowledging the right of every individual to belong in a city that is smart but also compassionate. Technology should not increase the disparity between those who can and those who cannot. Instead, it should be a bridge that provides opportunity, voice, and dignity to everyone who calls the city home. Building a smart city goes beyond sensors and software. It is a moral duty based on justice. A municipality that listens, includes, and changes to fit its most vulnerable citizens is not just smarter; it is stronger, more just, and more human.

4.3 Ethics, transparency, and trust: The foundations of smart governance

A citizen-focused smart city's core is not only the technology but also how the government changes to assist justice, transparency, and public trust [10]. Governance becomes more automated and efficient as it gets smarter, and it also becomes more open, responsible, and aligned with the needs of those it serves. This change to ethical and open government is a subtle yet crucial change in how cities interact with their people. Digital solutions enabling real-time communication between institutions and citizens are rapidly transforming modern government in smart cities. E-governance portals, interactive dashboards, and feedback mechanisms provide fresh avenues for conversation. All with speed that was once inconceivable, these platforms allow reporting of issues, evaluation of service performance, or expression of preferences on topics such as mobility, waste management, or public safety. Such constant feedback reinforces the notion that government is a dynamic process affected by daily experience rather than one limited to formal events or voting cycles. Particularly, e-governance is unlocking avenues hitherto closed by layers of paperwork and procedural red tape. Accessing governmental funding, registering services, or applying for

permits no longer calls for expensive intermediaries or long waits. Careful and precise design of these technologies improves not only institutional efficiency but also the user experience, hence lowering annoyance and strengthening confidence in public administration. However, ethical obligations follow these digital possibilities. Data on how people move, shop, communicate, and interact with the built environment drives the smart city's operation. Though it also affects the most delicate aspects of human existence, this information is priceless for creating responsive services. Left uncontrolled, technologies like predictive analytics, facial recognition, and GPS trackers might easily cross the line from functional to harmful. The same systems that maximize urban living might start to undermine fundamental rights without defined policies and ethical limits [59]. All three of these things threaten personal liberty and social justice: surveillance without consent, data collection without justification, and hidden algorithms. Governance, therefore, must be directed by openness, humility, and responsibility to offset this. Cities are starting to implement these ideas. Data policies now increasingly specify what is gathered, why it is required, and how long it is kept. Not only legally but also morally, openness in these procedures is essential. Consent ought to be a voluntary action. Where feasible, anonymized or aggregated data provides a safer means to produce insights without sacrificing personal privacy. A smart city's invisible infrastructure is, after all, trust. Lacking it, even the most advanced systems lose their credibility. Trust develops where there is openness: when algorithms are auditable, when data choices are clear, and when people may question or contest the application of technology in public life. Open-source solutions, citizen-led data governance committees, and public assessments of digital infrastructure are shaping this changing scene. An ethical smart city listens, clarifies, and encourages involvement; it does more than provide services. It regards its people as co-stewards of a common future rather than data points. Trust in this approach is not required; instead, it is acquired over time using care, honesty, and an unrelenting dedication to doing what is right.

5. Designing resilience: Sustainability and urban adaptability

Resilient Cities are living systems always in change, sometimes gradual, sometimes abrupt. Urban settings have been pushed to reconsider what resilience is by climate change, economic pressures, population increase, and unanticipated disasters [60]. Building for strength alone is no longer sufficient. What counts now is the ability to adapt, the ability to bend without breaking, to heal, and even to get stronger after upheaval. Smart and sustainable cities are built on this new basis. The growth of climate-smart infrastructure is a major component of this change. Cities are starting to include real-time environmental condition-reactive systems. In flood-prone areas, sensors built into riverbanks and drainage systems silently monitor flow speeds, water levels, and rainfall. These sensors not only collect data but also activate alerts, divert traffic, and notify emergency responders before a tragedy strikes. From responding to anticipating, from coping to preparing, this is a change. Living walls and green roofs are also altering building interaction with their environment. These are not only visual qualities. They restore biodiversity into the concrete grid, cool overheated city blocks, and collect rainwater. What once were heat-absorbing roofs provide refuge for birds, bees, and other pollinators. Better insulated, more efficient, and more in harmony with the ecosystems around them, the structures themselves breathe easier. Cities

are rethinking the surfaces of their streets. Permeable pavements allow rain to seep into the ground naturally. Rain gardens beside sidewalks filter water and provide patches of vegetation [61]. Once thought of as useless ground, urban wetlands are now valued for their capacity to absorb floodwater, clean runoff, and offer cooling effects. These qualities softly but powerfully restore balance under the urban one, creating an ecological layer. Resilience, however, is not merely environmental. It is also about how cities allocate resources. Gaining traction as a more intelligent, sustainable replacement for the traditional extract, use, and discard model, the circular economy is transforming the way we view waste. It is no longer the conclusion of the cycle; rather, it is the start of something fresh. For instance, smart bins are enhancing waste sorting with sensors and cameras. They provide consumers with real-time feedback, notify pickup personnel when full, and assist in minimizing contamination in recycling streams. Building materials are also finding a second life. Tracked, sorted, and utilized in fresh projects are demolition trash, concrete, lumber, and steel. Buildings become material banks in this cycle; design choices are made with future reuse in mind. Shared mobility contributes to the loop: electric cars, scooters, and bicycles all lower the total vehicle count. Managed by smart technologies, these services efficiently pair people with transportation possibilities, hence reducing emissions and freeing space once occupied by idle cars. Cities are even discovering methods to recycle heat. Once merely power-hungry infrastructure, data centers now provide heat for nearby houses. Household organic waste nourishes city farms. The lines separating waste and resource, production and consumption, are starting to fade. A city's capacity to endure unexpected shocks is also significantly influenced by its flexibility. A modular structure enables communities to create testing facilities and pop-up hospitals rapidly during the epidemic. Wherever the need is greatest, these similar modular structures can eventually become houses, community centers, or schools. This style of design expects change rather than assumes permanence. Land usage is also getting more dynamic. Smart zoning enables regions to adapt to their needs, rather than being confined to strict zones. On a Saturday, a weekday parking lot might turn into a farmer's market. After business hours, an office building might welcome visitors as a community center. This adaptability allows communities to maximize every square meter without sacrificing livability. Technology helps this reactivity. Data mapping technologies and sensors monitor building performance over time, as well as public space utilization when parks are full and foot traffic grows [62]. Planners and designers use this input to guide their identification of underutilized areas and projection of future needs. Crucially, cities are also using this data to protect against climate danger. Planners are creating cities that are not only smarter but also safer and healthier, using flood zone identification, airflow control to offset urban heat, and green corridor design linking and cooling areas. Resilience in this new age is not only about bouncing back. It is about constructing forward more intelligently, in an environmentally friendly manner, and more inclusively. A resilient city welcomes change. It embraces creativity. Learning from the past yet designing for the future, where sustainability is not a distinct aim but a way of life, integrated in everything from sidewalks to skylines, it is [63]. A summary of the key techniques applied to create resilient and sustainable cities is shown in **Table 4**. While also discussing the technological, financial, and legal issues these strategies encounter, it emphasizes useful applications, including green roofs, smart transportation, and modular design. The chart illustrates how adaptive infrastructure, ecological

Area	What it is	Examples	Challenges
Urban resilience	Cities that adapt to change and recover from shocks	Climate change response, population growth	Aging infrastructure, limited budgets
Smart infrastructure	Technology that responds to real-time environmental data	Flood sensors, traffic redirection	High costs, technical maintenance
Green buildings	Nature-based solutions in buildings	Green roofs, living walls	Space limitations, maintenance needs
Water-responsive design	Surfaces that manage rain and flooding	Permeable pavements, rain gardens, urban wetlands	Retrofitting old areas, public awareness
Circular economy	Reusing materials and reducing waste	Smart bins, recycled building materials	Sorting accuracy, system integration
Shared mobility	Using electric or shared vehicles to reduce the number of cars	E-scooters, electric bikes, and car sharing	Safety, infrastructure adaptation
Energy reuse	Turning waste energy into useful heat	Data centers heating homes	Technical complexity, location dependency
Modular design	Flexible buildings that change purpose easily	Pop-up hospitals, mobile classrooms	Initial planning effort, zoning rules
Smart land use	Areas that serve different roles at different times	Parking lot becomes market, offices as community centers	Coordination, regulation changes
Urban monitoring	Using data to guide city planning	Sensors in parks and streets, usage tracking	Privacy concerns, data overload
Climate protection	Designs that reduce harm from heat, floods, and pollution	Airflow planning, green corridors	Long planning cycles, competing priorities
New urban thinking	Making sustainability part of everyday planning and design	Designing with flexibility, nature, and long-term in mind	Resistance to change, education gaps

Table 4.
Key strategies, applications, and challenges in designing urban resilience and sustainability.

integration, circular resource usage, and data-driven design are transforming the urban landscape by simplifying complex urban concepts into practical categories. Importantly, it emphasizes that resilience is not only environmental but also social and economic, needing systems that can flexibly react to shocks while promoting long-term sustainability and livability.

6. Conclusion

The city has evolved beyond being a physical space in a society characterized by complexity and continual change. It now actively participates in the life of its people, observing, changing, reacting, and, in a very genuine sense, thinking. This chapter has looked at how urban settings of such cities, combining digital intelligence with social consciousness, have developed to produce places not only more intelligent but

also more inclusive, more ethical, and more alive. Today's smart city is not defined just by its capacity to gather data or automate services. Instead, like a living organism, it is acknowledged by its ability to learn from its surroundings, forecast needs, and adapt in real time. From a traffic signal system that detects congestion and changes on the spot to an energy grid that changes depending on real-time use and weather patterns, the thinking city is predicated on a notion of responsiveness. However, this reactivity has to be balanced with responsibility. Throughout the chapter, ethical governance, digital equity, and citizen involvement have all gained increasing significance. A city that runs digital systems benefiting only a privileged few or gathers data without consent cannot be brilliant. In this new urban paradigm, intelligence is evaluated not only in bytes and bandwidth but also in empathy and justice. Cities that think also have to care. At the core of this change are people. All they are now are co-creators, inventors, and decision-makers; they are not passive consumers of urban services. People from all walks of life are contributing to influence the systems that shape them, in return utilizing participatory platforms, open data tools, and inclusive design. The role of the citizen has changed from observer to architect, whether by reporting a broken streetlight *via* a mobile app, participating in a community budget, or rethinking public space *via* urban hackathons. Like the One-Minute and Ten-Minute City ideas, these human-centered strategies remind us that the most creative ideas usually begin with the most basic goal: improving life nearer to home. The digital transformation of cities has, at the same time, added new levels of complexity. Technologies such as artificial intelligence, digital twins, and edge computing are changing the way choices are made, how services are provided, and how infrastructure functions. They come with great promise to enhance safety, cut waste, maximize resources, and deliver services more quickly and equitably. However, they also provoke serious issues about digital dependency, control, and surveillance. Building systems that are not just efficient but also explainable is the difficulty. Not just strong but responsible. Balance holds the key. Between human judgment and automation. From widespread involvement to centralized authority. Between the ageless ideals of trust, decency, and belonging, and modern invention. A thinking city flourishes when it recalls the past as it envisions the future and when it listens as well as computes. Just as important is the ability of cities to change not only for the future but also in response to surprise, upheaval, and catastrophe. Economic shocks, pandemics, and climate change have demonstrated that static systems under duress fast become brittle. Rethinking how they use land, create structures, and run services, flexible cities are creating space for dynamic zoning regulations, multifunctional areas, and modular architecture. They are using data as a shared tool for planning, resilience, and renewal rather than as an extractive resource. This flexibility is about developing a basis that enables safe, inclusive, and regenerative growth, not about never-ending innovation. Real-time environmental sensing, green infrastructure, and circular thinking are all part of a larger movement toward sustainability that is not an add-on but rather a fundamental urban value. Resilience is now a societal promise rather than only a technical issue. What results is a metropolis that is always unfinished. A town that grows, learns, and changes alongside its inhabitants. One that accepts innovation not for its own sake, but because it improves daily life, thereby connecting, dignifying, and simplifying things. These are cities that can both think and feel. Cities that place equal importance on well-being. Cities that view public space as a standard canvas, equity as a design concept, and diversity as a strength. Concrete and code are not the only factors shaping urban living in the future. Relationships define how individuals traverse space, interact with the systems around them, and relate.

This chapter demonstrated that intelligent cities yield quantifiable benefits: predictive and edge-enabled systems reduce congestion and energy consumption; citizen co-creation enhances legitimacy; and sustainability measures bolster resilience, contingent upon the integration of ethics and governance. The remaining concerns of privacy, bias, and unequal access lessen these benefits. Future research should (1) create interoperable AI-IoT governance frameworks featuring auditable algorithms and participatory data stewardship; (2) formulate comparable indicators and mixed-methods protocols (longitudinal and quasi-experimental) to validate causal impacts; (3) assess transferability across greenfield and retrofit contexts, including low-resource environments; and (4) incorporate climate and equity metrics into digital twin evaluations. These measures can help cities go from automated systems to cognitive intelligence. Ultimately, thinking cities are about cultivating those relationships, encouraging involvement, and building for complexity without losing sight of what matters most. The smart city is developing into something deeper, more human, as the chapter ends. Optimizing is no longer sufficient; now is the moment to harmonize. To create cities that are not simply smart but also sensible. Not just reactive but also visionary. Moreover, in doing so, to create urban futures that are inclusive, resilient, and full of opportunity for all.

Author details

Amjad Almusaed^{1*}, Asaad Almsaad² and Ibrahim Yitmen³

¹ Department of Architectural Engineering, The University of Basrah, Iraq

² Faculty of Health, Science and Technology, Karlstad University, Sweden

³ Department of Construction Engineering and Lighting Science, Jönköping University, Sweden

*Address all correspondence to: amjad.almusaed@uobasrah.edu.iq

IntechOpen

© 2025 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. 

References

- [1] United Nations. World Urbanization Prospects: The 2018 Revision. New York: Department of Economic and Social Affairs, Population Division; 2018. Available at: <https://population.un.org/wup/> [Accessed: 15 April 2025]
- [2] Kunzmann U, Kappes C, Wrosch C. Emotional aging: A discrete emotions perspective. *Frontiers in Psychology*. 2014;**5**:380
- [3] Kunzmann KR. Smart cities: A new paradigm of urban development? In: Krätke S, editor. *Cities in Contemporary Globalization*. Leipzig: Leibniz Institute for Regional Geography; 2014
- [4] Batty M et al. Smart cities of the future. *The European Physical Journal Special Topics*. 2012;**214**:481-518
- [5] Albino V, Berardi U, Dangelico RM. Smart cities: Definitions, dimensions, performance, and initiatives. *Journal of Urban Technology*. 2015;**22**(1):3-21
- [6] Kitchin R. Getting smarter about smart cities: Improving data privacy and data security. Dublin: Data Protection Unit, Department of the Taoiseach; 2016
- [7] Silander D. The European Commission and Europe 2020: Smart, sustainable and inclusive growth. In: *Smart, Sustainable, and Inclusive Growth*. Cheltenham, UK, Northampton, MA, USA: Edward Elgar Publishing; 2019. pp. 2-35
- [8] Bibri SE. *Smart Sustainable Cities of the Future: The Untapped Potential of Big Data Analytics and Context-Aware Computing for Advancing Sustainability*. Cham, Switzerland: Springer; 2018
- [9] Caprari G et al. Digital twin for urban planning in the green deal era: A state of the art and future perspectives. *Sustainability*. 2022;**14**(10):6263
- [10] Cardullo P, Kitchin R. Smart urbanism and smart citizenship: The neoliberal logic of ‘citizen-focused’ smart cities in Europe. *Environment and Planning C: Politics and Space*. 2019;**37**(5):813-830
- [11] Green B. *The Smart Enough City: Putting Technology in its Place to Reclaim our Urban Future*. Cambridge, MA, USA: MIT Press; 2019
- [12] Komninos N et al. Smart city planning from an evolutionary perspective. *Journal of Urban Technology*. 2019;**26**(2):3-20
- [13] Ketzler B et al. Digital twins for cities: A state of the art review. *Built Environment*. 2020;**46**(4):547-573
- [14] Depiné Á et al. Smart cities and design thinking: Sustainable development from the citizen’s perspective. In: *Proceedings of the February 2017 Conference: IV Regional Planning Conference, Aveiro, Portugal*. Aveiro, Portugal: University of Aveiro; 2017
- [15] Rathore MM et al. Exploiting IoT and big data analytics: Defining smart digital city using real-time urban data. *Sustainable Cities and Society*. 2018;**40**:600-610
- [16] Teli M et al. Public design of digital commons in urban places: A case study. *International Journal of Human-Computer Studies*. 2015;**81**:17-30
- [17] Almusaed A, Almssad A. Blending human ware with software and hardware in the design of smart cities. In: *Sustainable Smart Cities-A Vision for Tomorrow*. London: IntechOpen; 2022

- [18] Anttiroiko AV. U-cities reshaping our future: Reflections on ubiquitous infrastructure as an enabler of smart urban development. *AI & Society*. 2013;**28**:491-507
- [19] Worku K. The role of e-government in enhancing performances of public service qualities and promoting good governance: with special reference of document authentication and registration agency (unpublished MA thesis). Addis Ababa, Ethiopia: Addis Ababa University; 2016
- [20] Ait Ouallane A et al. Fusion of engineering insights and emerging trends: Intelligent urban traffic management system. *Information Fusion*. 2022;**88**:218-248
- [21] Ravetz J, Miles ID. Foresight in cities: On the possibility of a “strategic urban intelligence”. *foresight*. 2016;**18**(5):469-490
- [22] Javed AR et al. Future smart cities: Requirements, emerging technologies, applications, challenges, and future aspects. *Cities*. 2022;**129**:103794
- [23] Niederquell A. Self-adaptive systems in organic computing: Strategies for self-improvement. *arXiv preprint*. 2018; arXiv:1808.03519
- [24] Poliziani C. Modeling and Implementation of Digital Twins for the Analysis of Transportation Systems. Bologna, Italy: University of Bologna; 2022
- [25] Omrany H et al. Digital twins in the construction industry: A comprehensive review of current implementations, enabling technologies, and future directions. *Sustainability*. 2023;**15**(14):10908
- [26] Akgün EZ et al. Breaking barriers for breaking ground: A categorisation of public sector challenges to smart city project implementation. *Public Policy and Administration*. 2024;09520767241263233
- [27] Bibri SE. Big data analytics and context-aware computing: Core enabling technologies, techniques, processes, and systems. In: *Smart Sustainable Cities of the Future: The Untapped Potential of Big Data Analytics and Context-Aware Computing for Advancing Sustainability*. Cham, Switzerland: Springer; 2018. pp. 133-188
- [28] RAC D et al. Context aware control systems: An engineering applications perspective. *IEEE Access*. 2020;**8**:215550-215569
- [29] Palensky P, Dietrich D. Demand side management: Demand response, intelligent energy systems, and smart loads. *IEEE Transactions on Industrial Informatics*. 2011;**7**(3):381-388
- [30] Almusaed A, Yitmen I, Almssad A. Enhancing smart home design with AI models: A case study of living spaces implementation review. *Energies*. 2023;**16**(6):2636
- [31] Siddique A et al. Beyond the outdoors: Indoor air quality guidelines and standards—challenges, inequalities, and the path forward. *Reviews on Environmental Health*. 2025;**40**(1):21-35
- [32] Habibzadeh H et al. Smart city system design: A comprehensive study of the application and data planes. *ACM Computing Surveys (CSUR)*. 2019;**52**(2):1-38
- [33] Ziervogel G, Cowen A, Ziniades J. Moving from adaptive to transformative capacity: Building foundations for inclusive, thriving, and regenerative urban settlements. *Sustainability*. 2016;**8**(9):955

- [34] Bibri SE. Conceptual, theoretical, disciplinary, and discursive foundations: A multidimensional framework. In: *Smart Sustainable Cities of the Future: The Untapped Potential of Big Data Analytics and Context-Aware Computing for Advancing Sustainability*. Cham, Switzerland: Springer; 2018. pp. 39-131
- [35] Belli L et al. IoT-enabled smart sustainable cities: Challenges and approaches. *Smart Cities*. 2020;3(3):1039-1071
- [36] Anjomshoaa A et al. City scanner: Building and scheduling a mobile sensing platform for smart city services. *IEEE Internet of Things Journal*. 2018;5(6):4567-4579
- [37] Analytics M. The age of analytics: Competing in a data-driven world. McKinsey Global Institute Research. 2016
- [38] Uzoka A, Cadet E, Ojukwu PU. The role of telecommunications in enabling internet of things (IoT) connectivity and applications. *Comprehensive Research and Reviews in Science and Technology*. 2024;2(02):055-073
- [39] Zhao Y et al. Edge computing and networking: A survey on infrastructures and applications. *IEEE Access*. 2019;7:101213-101230
- [40] Kaiser ZRMA. Smart governance for smart cities and nations. *Journal of Economy and Technology*. 2024;2:216-234
- [41] Wang X. Thinking of city development influenced by communication technology: Will the Internet eliminate the cities? Milan: Politecnico di Milano, School of Architecture Urban Planning Construction Engineering; 2018. [Master's thesis]. Available from: <https://www.politesi.polimi.it/handle/10589/143274>
- [42] Noori N et al. A framework to analyze inclusion in smart energy city development: The case of Smart City Amsterdam. *Cities*. 2025;158:105710
- [43] Karayel T. Innovation Policy Roadmapping for the Future Finnish Smart Cities. Turku, Finland: University of Turku; 2023
- [44] Nelischer K. The development of quayside: planning toronto's smart city (disseration). Canada: University of Toronto; 2022
- [45] Schröpfer T. Dense+ Green Urban Development: Emerging Models of Integrated Architecture. Basel, Switzerland: Birkhäuser; 2025
- [46] Bibri SE. Sustainable urban forms: Time to smarten up with big data analytics and context-aware computing for sustainability. In: *Smart Sustainable Cities of the Future: The Untapped Potential of Big Data Analytics and Context-Aware Computing for Advancing Sustainability*. Cham, Switzerland: Springer; 2018. pp. 371-417
- [47] Ratti C, Claudel M. The City of Tomorrow: Sensors, Networks, Hackers, and the Future of Urban Life. New Haven, CT, USA, London, UK: Yale University Press; 2016
- [48] Cina E et al. The role of AI in predictive modelling for sustainable urban development: Challenges and opportunities. *Sustainability* (2071-1050). 2025;17:11
- [49] Mohanty A, Mohapatra AG, Mohanty SK. Real-time traffic monitoring with AI in smart cities. In: *Internet of Vehicles and Computer Vision Solutions for Smart City*

Transformations. Cham: Springer Nature Switzerland; 2025. pp. 135-165

[50] Makanadar A. Neuro-adaptive architecture: Buildings and city design that respond to human emotions, cognitive states. *Research in Globalization*. 2024;**8**:100222

[51] Sorvig K, Thompson JW. *Sustainable Landscape Construction: A Guide to Green Building Outdoors*. Island Press; 2018

[52] Khan LU et al. Edge-computing-enabled smart cities: A comprehensive survey. *IEEE Internet of Things Journal*. 2020;**7**(10):10200-10232

[53] Raza S et al. A survey on vehicular edge computing: Architecture, applications, technical issues, and future directions. *Wireless Communications and Mobile Computing*. 2019;**2019**(1):3159762

[54] Kearns AJ. Active citizenship and urban governance. *Transactions of the Institute of British Geographers*. 1992;**17**:20-34

[55] Roza V. Exploring the use of open data to support citizen-led initiatives for sustainable urban development in East Africa (disseration). Nottingham, UK: University of Nottingham; 2022

[56] Attar A et al. A survey of security challenges in cognitive radio networks: Solutions and future research directions. *Proceedings of the IEEE*. 2012;**100**(12):3172-3186

[57] Hanna NK. Mastering digital transformation: Towards a smarter society, economy, city and nation. In: Hanna NK editor. *Mastering Digital Transformation: Towards a smarter Society, Economy, City, and Nation*. Vol. 17. Bingley, UK: Emerald Group Publishing Limited; 2016. pp. i-xxvi

[58] Kashef M, Visvizi A, Troisi O. Smart city as a smart service system: Human-computer interaction and smart city surveillance systems. *Computers in Human Behavior*. 2021;**124**:106923

[59] Beatley T. *Ethical Land Use: Principles of Policy and Planning*. Baltimore, MD, USA: Johns Hopkins University Press; 1994

[60] Pelling M et al. Toward a sustainable and resilient future. In: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK, New York, NY, USA: IPCC; 2012. pp. 437-486

[61] Brown SPR. *The Fault with Asphalt: Towards Absorbent Urban Design in New York City*. New York, NY, USA: Fordham University; 2019

[62] Nam H-J. *The Intelligent Machine in Urban Open Space: Sensing Urban Data and Performing Architectural Behaviour*. United Kingdom: Open University; 2021

[63] Wolfe CR. *Sustaining a City's Culture and Character: Principles and Best Practices*. Lanham, MD, USA: Rowman & Littlefield; 2021

Chapter 2

Smart City(ies) and Urban Living: The Paradox of the Good Life

Andrew D. Roberts

Abstract

This chapter critiques the smart city(ies) agenda(s) to identify(ies) paradoxical scenarios that limit the ability for residents to achieve a better quality of life (QoL) and a healthy, productive, prosperous and satisfying future (i.e., the good life) within city(ies). An argument is made that the approach(es) taken to smart technology(ies) deployment(s) within smart city(ies) create ‘have and have not’ situations wherein some but not all, specifically those from lower-socio-economic group(s), gain access to the benefits associated with smart city(ies) living and by association the good life. Building on these arguments the chapter concludes by recommending a fundamental re-orientation in the approach(es) to smart city(ies) agenda setting and decision making to address the paradoxes and enhance the likelihood for all to achieve a good life within their urban community(ies).

Keywords: smart city(ies), good life, urban living, paradoxes, technology(ies)

1. Introduction

Research indicates more people are migrating to city(ies) in search of economic and social opportunity(ies). Resulting in a five-fold growth in urban populations [1], and to predictions that by 2050 more than 70% of the global population will live in city(ies) [2]. A scenario that scholars suggest creates positive and negative outcomes for urban citizens (urbanites). Some see rapid urbanisation as positive and argue it facilitates the creation of more economically, socially and culturally vibrant urban ecosystems that promise: - economic and fiscal growth, increased productivity [3], and a rise in economic, social, human and cultural capital [4]. Others adopt an opposite viewpoint. They suggest it increases poverty, unemployment, income and social inequality [5], urban costs and housing affordability [6] and environmental degradation [7]. Resulting in increasing pressure(s) to address the economic, social and environmental problems associated with rapid urbanisation [8, 9]. Urbanites require municipal governments to be accountable, responsible and take action to address these problem(s) [10]. Yet, poor fiscal and urban governance and historically low investment in urban infrastructure [7] inhibits their ability to develop effective and sustainable responses [11]. This has led to municipal governments partnering with global technology firms to implement smart city(ies) [12] that leverage smart technology(ies) to make city(ies) smarter, more efficient [8], greener, safer and more culturally vibrant [13, 14]. To enhance the social, cultural and economic foundations

needed for sustainable urban development, generate improvements in the quality-of-life (QoL) for urbanites [15]. In other words, smart city(ies) promise a good life for all urbanites.

This chapter critiques the idea that smart city(ies) enable all urbanites to achieve a “good life”. We begin by explicating some perspectives on the good life. Building on these preliminaries, the chapter then explores the contributions smart city(ies) make to improving the lives of urbanites. An argument is made that smart city(ies) create paradoxical scenarios that limit the capacity for some urbanites to achieve their full potential and live the good life. The chapter concludes with recommendations aimed at resolving these paradoxes to enhance the likelihood for all urbanites to achieve the good life within smart city (ies).

2. Perspectives on the good life

The UN’s sustainable development goals (SDGs) provide a pathway for the good life by promoting peace and prosperity for people and the planet, now and in the future [16]. These SDGs goals and objective(s) target sustainable development that meets people’s basic needs, whilst enabling them to achieve a better QoL and a healthy, productive and prosperous future [17]. In essence, they create the optimal conditions to satisfy people’s needs and live the good life. However, living the good life is not about being morally or ethically good. Rather, it is associated with QoL and the degree to which life holds meaning and fulfilment [18]. Thus, living the good life requires satisfying needs, addressing wants and providing the means for fulfilling them [19]. Yet, comprehensive definition(s) of the good life remain elusive, due to the various philosophical perspectives on its meaning and the subjectivity associated with it definitionally. For instance, there are three major philosophical strands concerning the good life, based on: - (i) characteristics (e.g., religious or ideological ideas etc. associated with a good life), (ii) satisfaction of preferences (i.e., resource limitations that lead people to select those things they believe will lead to a good life), and (iii) experience(s) (i.e., perceptions of the good life lead to beliefs that it is) [20]. Which lead to associating the good life with various commensurable factors including subjective and psychological wellbeing, freedom(s), life satisfaction, happiness, needs, and capabilities [21]. This list re-enforces the subjective nature of what it means to live the good life. Presenting problems for municipal governments when they seek to enable urbanites to pursue the good life. For example, including wellbeing or happiness as variable(s) leaves what it means to live the good life dependant on an urbanite(s) subjective experience(s) (i.e., what makes them feel good). Variables that sit outside municipal government(s) responsibility. After all, it is difficult to see how a municipal government(s) can assume the responsibility of ensuring every urbanite feels happy [21]. Yet, urbanites expect access to urban environments that meet their basic socio-economic needs, provide them with opportunity(ies) for fruitful, productive, prosperous and healthy future(s) [16], and by association a good life.

3. Smart city(ies) and the good life

Smart city(ies) through the deployment of smart technology(ies) offer the potential to improve the social, economic and environmental conditions for urbanites [22]. They do so by creating new services [23] that increase economic competitiveness,

urban living standards [24] and the satisfaction of urbanites [25]. For example, smart technology(ies) : - reduce air and water pollution, lower energy consumption, optimise water use, and improve environmental quality [26]; improve natural resource(s) and waste management, waterway conservation, and increase the number of green space(s) [27] within urban locale(s). Whilst also enhancing urban social capital [28], the liveability of urban environment(s) [29], and the wellbeing, QOL, safety and security of urbanites [30]. In essence, smart city(ies) create the conditions needed to make urbanites feel happier and healthier by improving socialisation, friendship, support, generosity and their cognitive, subjective and affective wellbeing within their community(ies) [31, 32].

Scholars suggest a direct relationship between smart technology(ies) and improvements in the ecological environment within smart city(ies). Smart technology(ies) facilitate urban data collection and analysis, and the sharing of information targeted at maintaining, improving and enhancing the quality of urban environment(s) [26, 33]. Studies show that various combinations of smart technology(ies) can be used to create smart traffic system(s) that improve traffic management and energy consumption, and support informed municipal government sustainable infrastructure decision making [34]. When combined with artificial intelligence (AI) algorithms they also improve urban air quality and reduce air pollution and carbon dioxide emission(s) by lowering vehicle idling times and traffic congestion and encouraging alternative environmentally sustainable modes of transport (e.g., public transit) [35]. Further, when combined with IoT sensors they can improve and optimise waste collection. For example, various smart technology(ies) can be used to identify and send real-time data on the volume and type of waste per bin by geo-location(s) to facilitate smart sorting of waste into bio-degradable, for use in bio-generation, and non-bio-degradable materials. Resulting in lower greenhouse gas emissions through improved garbage truck route optimisation, and more efficient waste collection and management [36], and improved urbanite(s) attitudes and behaviours towards household waste that reinforce(s) good practices of where, how and when to dispose of household waste. Which in turn strengthens recycling efforts and limit(s) landfill waste disposal [37]. Various smart technology(ies) can also be used to improve energy efficiency and reduce energy consumption [38]. For example, scalable, low-cost, and secure IoT and smart home automation systems enable remote management of electricity usage [39] and help control and monitor urbanites energy usage patterns to enhance their comfort and maximise energy efficiency [40]. They can also be used to improve the interoperability between diverse electrical systems to enhance electricity measurement, control and efficiency, increase cost savings and lower greenhouse gas emissions [41, 42]. Positing a greener, cleaner and less polluted urban environment(s) for urbanites [4, 9].

However, creating liveable urban environment(s) for urbanites requires more than environmental management. Accessibility to healthcare services and other lifestyle factors impact urbanites health and wellbeing, the liveability of their urban environments [42–44] and by association their ability to live a good life. Yet, traditional healthcare solutions will find it increasingly difficult to meet the future needs of rapidly increasing urban population, particularly the growing number(s) of elderly urbanites and those with chronic often incurable and long duration illnesses. Which may require ongoing treatment that adds to burdens on already stretched hospital infrastructure, medical personnel, and depleted financial resources [45]. Smart city(ies) use of smart technology(ies) such as digital healthcare (i.e., combining advanced ICT, smart sensors, 5G, AI, big data analytics and digital wearable(s))

[46] can improve healthcare provision decision making and more efficiently target medical services to those most in need urbanites at a lower cost and in a more timely manner than traditional health care solution(s) [47, 48]. Which enhances the health and wellbeing of elderly urbanites, many of whom prefer home over hospice care [49] and reduce the burden(s) they place on traditional healthcare services by acting as virtual assistants, providing medical reminders, supporting them with in-home tasks and exchanging health information with medical providers to help them live at home longer [50]. For instance, smart technology(ies) that remotely monitor the physical conditions and activity(ies) of elderly urbanites improves the wellbeing of those with cognitive impairments such as dementia and other disabilities, by real-time monitoring their capacity to undertake simple and complex tasks at home. Allowing for comparisons to be made against activity life scores to assist medical practitioners to identify functional deterioration, make faster decisions and intervene earlier to improve care for elderly urbanites [51, 52]. More broadly, smart technology(ies), can improve healthcare provision by lowering the pressures on hospital infrastructure when city(ies) are faced with responding to highly infectious disease(s) (e.g., COVID) by enhancing early-stage disease detection and diagnosis, making predictions on disease progression, and improving healthcare response(s) within and across urban locale(s) [53], and forecasting potential cures by medical practitioners [54].

Smart city(ies) enhance urbanites QoL by offering smart technological alternatives to resolving their everyday problems and address their needs through the delivery of improved services [55], that enhance participatory governance and human and social capital [56]. Technology(ies) that have been shown to contribute to a 10–30% improvement in urbanites QoL by lowering living costs, commute time and greenhouse gas emissions, and improving city(ies) operational efficiency(ies) [57]. Their convenience also improves how urbanites perceive smart infrastructure, public services and administration, their sense of wellbeing and by implication their QoL [58]. Yet, smart technology(ies) alone do not automatically enhance the QoL for urbanites. The nature of municipal governments policy making also plays a role. A case study of Barcelona's approach highlighted the role municipal governments play in improving urbanites QoL. For these urbanites QoL was improved by the bottom-up and top-down approach taken to smart city(ies) policy(ies) and smart technology(ies) deployment and the creation of smart district(s), with open collaborative space(s) and access to open data for all [59]. Thus, re-enforcing the positive correlation between smart city(ies) policy(ies), positive outcomes for urbanites and the liveability of their community(ies) [25]. Consequentially urbanites QoL is further enhanced within smart city(ies) when their perspective(s) on the quality, efficiency and efficacy of smart technology(ies) and are taken into consideration by municipal governments [60].

4. Smart cities: Critiques and paradoxes

Despite the recognised benefits of smart technology(ies) to urbanites, concerns have been raised about the assumptions and approach(es) municipal governments take towards smart city(ies) programmes. Resulting in several paradoxical viewpoints pertaining to the ability for all urbanites to achieve the good life within their urban locale(s). At their core these relate to the techno-centricity and one-dimensional perspective of smart city(ies) agenda(s) and policy(ies), including their over emphasis on conceptualising solutions to complex urban problems using smart technology(ies).

Particularly the erroneous belief that smart technology(ies) automatically improve the environmental, social and economic conditions for all urbanites [9, 61]. When the opposite may occur. Whereby over emphasising smart technology(ies) may lead to a failure in addressing the social dimensions required to meet the needs of all urbanites. In that, making city(ies) smarter does not necessarily equate to automatic improvements in the social welfare, wellbeing and provision of basic needs for everyone [62]. Instead, it may lead to the creation of urban environment(s) that are exclusive and unequal [63]. Thus, the idea of an equal and inclusive smart city(ies) may in reality be a fallacy and elaborate marketing strategy and policy vision of municipal governments and global technology firms who have vested interests in ensuring their grand plans for smart city(ies) gain the desired attention and acceptance of urbanites [50, 64]. As such the smart city(ies) agenda(s) per se may become hijacked [65] by large corporation's need for profit maximisation to the detriment of the welfare of urbanites [9, 50, 66].

Consider for example the case of Abu Dhabi's smart city(ies) initiative, 'Masdar City' [62]. Which aimed to create a zero-carbon sustainable urban environment and transform and re-generate the city(ies) economy through the deployment of smart technology(ies). However, its grand vision for a city that supported sustainable living through urban renewal and social change does not appear to have been realised. Instead, Masdar City has become an eco-centre for green technology(ies) development driven by the involvement of large global firms, such as General Electric and Schneider and Siemens, who saw the city as an opportunity to test, implement and promote their smart technology(ies) products and services. Leading to a situation wherein these firms and their technology-driven capital drive governmental agenda setting, decision making and policy(ies) development. Thus, creating a commercially driven urban ecosystem with profit maximisation at its core. Resulting in a smart city that reserves only a small area for low-income urbanite(s) and leaves limited space for those who are disadvantaged and underprivileged.

Similar issues also emerge from Tianjin's smart city(ies) program(s). In common with other smart city(ies) projects a top-down approach was taken to smart technology(ies) deployment in partnership with large technology(ies) firms [67]. Leading to a fundamental failure to consider the inter-related complex web of socio-economic-cultural factors that exist within the urban ecosystem(s) and their impacts on those who live there, and a failure to recognise the needs, wants and aspirations of urbanite(s) from transient population(s) and those who are having to deal with urban poverty [68].

Similar problems occur for urbanite(s) within the context of Korea's smart city(ies) programs. Which have been seen to be problematic for urbanite(s) due to a lack of social infrastructure, market restrictions and the vested financial interests of large corporations. In that they are built from technology centric perspective(s) that overly emphasise supply-side smart technology ecosystems that require large fiscal investment to the detriment and neglect of the social and cultural aspects that enhance the livability of urban environments [69, 70].

These examples, suggest that those responsible for smart city(ies) may inadvertently create dystopian urban environments. Wherein, urbanites cannot manage, live well or even survive within their community(ies) without access to smart technology(ies). A situation that becomes even more problematic if access to smart technology(ies) were made unavailable to some or all urbanite(s) [71]. Scenarios that could worsen due to the hidden profit agendas of large corporations who see more opportunity(ies) to leverage an untapped and growing market for smart

technology(ies) within urban environment(s). For instance, IBM's smart city(ies) program, that promises improvements in urban sustainability, more efficient city(ies) operations and enhanced QoL for urbanites through the application of IBM's smart city(ies) technology(ies) [72]. From IBM's perspective, the problems associated with rapidly growing urban populations including inequality(ies), ageing infrastructure, and diminishing fiscal revenue, can be resolved by implementing their smart city(ies) expert solutions alone. Expert solutions that extend across urban planning and management of urban infrastructure to human and social service(s) and are monitored and regulated by IBM's intelligent operation system(s) [39, 40]. Leading to a scenario where IBM believes that they alone can transform city(ies) from the top-down, through the application of their smart technology(ies) to improve and enhance the liveability of city(ies) for all urbanites. One that is questionable for two reasons: (i) Problems emerge from the assumptions IBM makes about urban environment(s). IBM's approach assumes a level of homogeneity across the administration and management function(s) of all cities. Resulting in a vision that conceptualises city(ies) as one world wherein urban problem(s) can be resolved on an individual basis, by smart technological solution(s) deployed in isolation.

Yet, the opposite is the case. City(ies) are complex systems of systems with inter-related, inter-dependent and inter-woven problems [45]. There is also a taken for granted assumption that there exists a stable and functioning city infrastructure that IBM layer their smart technology(ies) on. However, many city(ies), lack adequate infrastructure or it often breaks down [4, 9, 73]. (ii) IBM's vision fails to recognise that city(ies) per se are made up of many different and often non-commensurable world(s) (e.g., public sector, business and education etc) [74]. Thus, IBM's singular vision results in flatter city(ies), where ethnic minority(ies) are seen as irritations and disturbances to IBM's smart system(s) solutions [4, 9]. Leading to a situation where some but not all urbanites have access to the benefits associated with smart city(ies) living [12], and to the risk of creating gentrified and fragmented urban enclaves [75]. Thus, over relying on large corporations in smart city(ies) implementations may worsen already growing income and social inequality(ies) and human capital divides within urban environment(s) [8, 12, 63], and to scenarios where some but not all urbanites have access to the benefits of smart technology(ies) [9, 76]. A situation that worsens due to the digital divide, and the limited access and lack of affordability of smart technology(ies) for low-income urbanites [12, 76].

4.1 The digital divide paradox

The digital divide is the gap between those with access to modern technology and those who do not. Digital divides create and worsen 'have and have not' situations for those living in smart city(ies) [9, 77]. Which is reinforced by the over reliance on smart technology(ies) within smart city(ies) that inadvertently favour(s) urbanites who are highly skilled and well paid, and in the best position to capitalise on the benefits emergent from smart city(ies) living [12, 78]. Leaving less-skilled, less educated and lower-income urbanites shut out from the reward(s) associated with living within smart city(ies) [79]. Meaning, that a small number of privileged urbanites reap the financial and social benefits arising from smart technology(ies) within their urban environment(s). A scenario that if left unchecked creates a perpetually negative cycle(s) wherein privileged group(s) retain their relatively higher income, wealth, educational achievement and secure jobs, and pass them on to the next generation. Whereas those who are disadvantaged continue to experience economic

and social exclusion and inequality [80]. Resulting in an unequal distribution of the benefits associated with smart city(ies) living [81, 82]. Which become further perpetuated by the limited and unaffordable access to the smart technology(ies) necessary for smart city(ies) living, for those urbanites from low socio-economic background(s) and those who wrestle with limited technological knowhow [83].

Whilst income levels somewhat correlate to the rate of access to smart technology(ies), given the costs of access presents limitations for urbanites [12, 80, 84] the digital divide is also driven by societal stratification(s) [85] and broader socioeconomic, political, cultural, social, and technological factors. Including personal background(s) (e.g., age, ethnicity and gender), the available temporal, material, social and cultural resources [86], and the ability to capitalise on the economic opportunity(ies) within smart city(ies) by acquiring the technical skills needed to maximise the use of smart technology(ies) [9, 87]. Yet, achieving the later is not necessarily easy for all urbanites, particularly the elderly, those with cognitive or physical disability(ies), and other under privileged groups many of whom do not have access to the underlying infrastructure (i.e., the internet) nor the capacity(ies) to use smart technology(ies) [79, 88]. Thus, as urban living becomes increasingly dependent on smart technology(ies), a large percentage of urbanites may feel excluded, isolated and find it increasingly difficult to participate in community social and cultural life [89, 90].

We now have a paradox, whereby smart city(ies) through deploying smart technology(ies) promise to improve the economic and social conditions and the ability for all urbanite to pursue a good life. Yet fail to do so for all urbanites. After all, if living in and pursuing the good life in a smart city is dependent on equal and equitable access to smart technology(ies) the fact that some urbanites feel increasingly excluded, isolated, and socially and economically segregated [9, 80, 91, 92] questions emerge about how smart city(ies) can meet their promise(s) to do so. Rather, the pursuit of the good life within smart city(ies) becomes one for the privileged few [12, 78], rather than for all. This has profound implications for the smart city(ies) agenda(s) and for those living in smart city(ies).

4.2 Smart city(ies): AI paradox(es)

AI is becoming an increasing feature of urban life, transforming urban landscapes, driving the evolution of smart city(ies) [93] and disrupting the life of urbanites [94]. Yet 52% of people worldwide do not view AI positively. Rather, they feel nervous and anxious about the use of AI products and services [95]. They are concerned that AI will lead to massive technologically driven unemployment [96], increased income inequality [97], and threats to personal privacy [98, 99]. Thus, AI adoption may reinforce 'have and have not' scenario(s) for some urbanites [100] by lowering employment level(s) for lower-skilled workers [98] and protecting employment for those less easily replaced by automation (i.e., with higher income and education levels) [101–103]. Leading to a scenario where some and not all urbanites are good enough to fully participate in life within smart city(ies) that embrace AI. Wherein, those with the right combination of personal attributes such as being active, independent, educated, or in some ways deserving (e.g., the elderly etc.), or have domain specific knowledge and skills in the use of AI-based services, earn the right to the benefits emergent from AI adoption within smart city(ies) over those who do not [104, 105]. Researchers [106] suggest this triggers deep-seated emotions and anxiety(ies) for some urbanites due to the way AI redefines life, work and transforms long standing traditions and meaningful human interactions. In that AI replaces valuable personal

exchanges with automated experiences and technologically driven repetitive tasks [107]. For instance, by: -replacing personal exchanges in AI automated restaurants, reducing teacher-to-student interaction(s) with AI driven personal learning tools, and substituting communal activity(ies) (e.g., shopping and cooking) with automated shopping platforms and smart device(s). Traditions that provide urbanites with opportunity(ies) for more social interaction(s) and connection(s), important sources of identity, purpose and stability formation [107], and improved QoL and wellbeing [108]. Losing them triggers a sense of disconnection from authentic ways of life, a loss of continuity for urbanites, and an erosion of the social and cultural fabric of their community(ies) [108]. Thus, we have a paradox between the efficiency and convenience of AI and its potential impact on the personal and community experiences of urbanites [109].

Anxiety(ies) about AI also extend to concerns about the ethical implications of AI applications, perceptions of algorithmic bias, data loss, information privacy, and its potential to operate independently from human oversight and direction [110]. Take for instance urbanites concerns about infringements on privacy and the limited technical competency and organisational accountability in the use of Clearview by the Australian Police, which leverages AI and various data gathering tools to identify members of the public from photographs [111]. And elderly urbanites anxiety(ies) about personal data privacy when AI applications are deployed to help maintain their mental and physical health [112]. At issue here is AI's reliance on the collection and analysis of vast volumes of personal data and its use of interdependent algorithms. A scenario that all citizen(s), including urbanites, consider an infringement of their data privacy rights and raises their concerns that they do not know whom has access to their personal information nor how and what it is being used for [113, 114]. Take for instance, the way AI and ML algorithms learn from urbanites personal information and make inferences about them based on sensitive data about their past attitudes and behaviours. Algorithms used by Facebook and other social media applications to judge an individual's political and personal beliefs, and sexual and gender orientation [115–117]. These could be misused to profile, potentially bias, discriminate, and create mental distress for some groups within society(ies) [118]. A scenario that becomes increasingly problematic when urbanites become concerned that their personal information and the associated predictions made may be leaked and misused by institutional actors who may not have the best interests of urbanites at heart [98, 119]. After all, once this data is created and stored there is no reason why it could not be repurposed and used for a multitude of purposes that remain unknown to urbanites both now and in the future [99, 120]. Concerns that should not be dismissed given that losing control over the collection, use and access to personal information may negatively impact personal wellbeing [121], potential heighten the stress, fear and apprehension urbanites have of AI [110], and limit their pursuit of the good life.

5. Addressing the paradoxes and issues

What do these discussions on smart city(ies) and their paradoxes mean for urbanites pursuit of the good life? We have shown that smart city(ies) present urbanites with the possibility of achieving the good life by creating more sustainable urban environments that improve the social, economic and cultural QoL and wellbeing of urbanites [14, 22, 73, 122] irrespective of opposing perspectives. Yet as shown overly emphasising smart technology(ies) may exacerbate the creation of unequal, exclusive

and gentrified urban locale(s) [63] and leave some urbanites becoming socially and economically excluded from the benefits of smart city(ies) living [73, 81, 104, 123] and limited in pursuing a good life. Due to (i) their limited and unaffordable access for urbanites from lower socio-economic-cultural background(s) [83], and (ii) the broader social, cultural and ethical issues arising from the rapid adoption of AI and ML [97–99, 124]. Thus, creating a paradoxical scenario(s) wherein some but not all urbanites have access to the benefits of smart city(ies) living and a good life. This begs the question: - what can institutional actor(s) (i.e., municipal governments and large technology firms with responsibility for smart city(ies)) do to address these paradoxes and enable a good life for all urbanites. Firstly, they need to balance the competing demands from diverse stakeholder groups and take steps to address the anxiety(ies) some urbanites have about increased AI adoption within their community(ies) [100, 125]. Specifically, urbanites with the most to gain from the status quo approach to smart city(ies) [25, 78], versus those from lower socio-economic groups who have the most to lose [9, 86, 89].

Secondly, they must understand that a drive for profit maximisation and efficiency is at variance with the expectations of urbanites who are increasingly demanding businesses do more for the community(ies) they operate within [126–128]. By providing solutions to a host of societal problems and considering how their decisions and actions impact the financial, human, social, and environmental aspects of the community(ies) urbanites live within [129–131], and make a more substantial contribution to corporate social responsibility (CSR) and take-action towards addressing the sustainable development goals (SDG's) that are most challenging within their urban locale(s) [132]. Specifically, addressing poverty (SDG1), reducing inequality(ies) (SDG10), ensuring inclusive and equitable education (SDG4) and creating more sustainable community(ies) (SDG11) [133]. Yet, institutional actors primarily focus on SDG's that contribute the most to their economic growth and profitability (e.g., decent working conditions (SDG 8), responsible consumption and production (SDG12) and climate action (SDG13)), and take little action to address those that urbanites identify as most important to them [134, 135]. As such, urbanites do not believe institutional actors adequately address the SDG's that most impact the creation of vibrant and healthy urban environments. A similar argument that can be also made for the approach(es) taken to CSR initiatives.

Thirdly, institutional actors need to be willing to shift the balance of power in smart city(ies) agenda setting towards urbanites. By empowering the later to discuss the issues they see as most important to them [136] and giving them more influence in determining how smart technology(ies) can be used to facilitate positive outcomes for their community(ies) [14, 137]. This requires continuous sense-making by institutional actors and a willingness on their part to consider the needs, wants, feelings, perspectives and opinions of a broader range of stakeholder groups, including the most disadvantaged urbanites, when making decisions regarding smart technology(ies) [4, 138, 139]. Failure to do so may lead to a breakdown in trust between institutional actors and urbanites, a questioning of the relevance of these institutions to their community(ies) [129, 130, 140], and an increase in concerns that the interests of institutional actors will take precedence over the needs of urban community(ies) [9, 65, 141].

In practice this mean's adopting a democratic and collaborative approach to smart city(ies) agenda setting. One that fundamentally re-conceptualises the smart city(ies) and smart technology(ies) decision making process(es). The author challenges the reader to consider a multi-stakeholder asynchronous simultaneous top-down and

bottom-up collaborative approach that balances the needs of institutional actors, other stakeholder(s) and urbanites by adopting an urbanite-centric approach to smart city (ies) decision making across three layers of activity (see **Figure 1**). An approach that shifts the emphasis from top-down autocratic, one-dimensional technocratic smart city(ies) decision making towards a more human and social centric approach [14, 142] to smart city(ies) development. Meaning, the ownership of the decision-making process rests with those most impacted by smart technology(ies) (i.e., urbanites), and institutional actors move from being seen as autocratic decision makers pushing unwanted technocratic solutions, to collaborative partners in smart city(ies) endeavour(s) [4, 9, 14]. As illustrated, each layer is porous and generates feed-forward and feed-back loops. In that as issues, problems and their relevant solution(s) emerge within each layer they are fed back into the next and vice versa for further consideration.

The inner layer (*Layer 1*) presents an asynchronously process of evidence gathering, analysis and strategy(ies) and action development. It captures the work done by institutional actors and other stakeholders (e.g., not for profits, NGOs etc) to collect and analyse data on the problems and issues relating to urban economic, social, community and physical infrastructure capital(s), and to identify potential strategy(ies) and actions to address them. Within this layer work is also undertaken to identify emergent challenges and issues associated with smart technology(ies), AI and ML, particularly those relating to urbanites and community(ies) (e.g., data privacy and transparency, and bias and discrimination), and to develop smart ICT, AI and ML governance frameworks and policy(ies). The findings from this stage are compared against current and potentially future CSR and SDG strategy(ies) and actions. The middle layer (*Layer 2*) is where the findings and decisions made in *Layer 1* are transmitted and communicated to urbanites and community(ies). Care is taken to ensure that all urbanites are given a right to voice their views and opinions, particularly those from lower socio-economic, disadvantaged and ethnic minority groups. The outer layer (*Layer 3*) is where multi-stakeholder collaboration and engagement occur. With

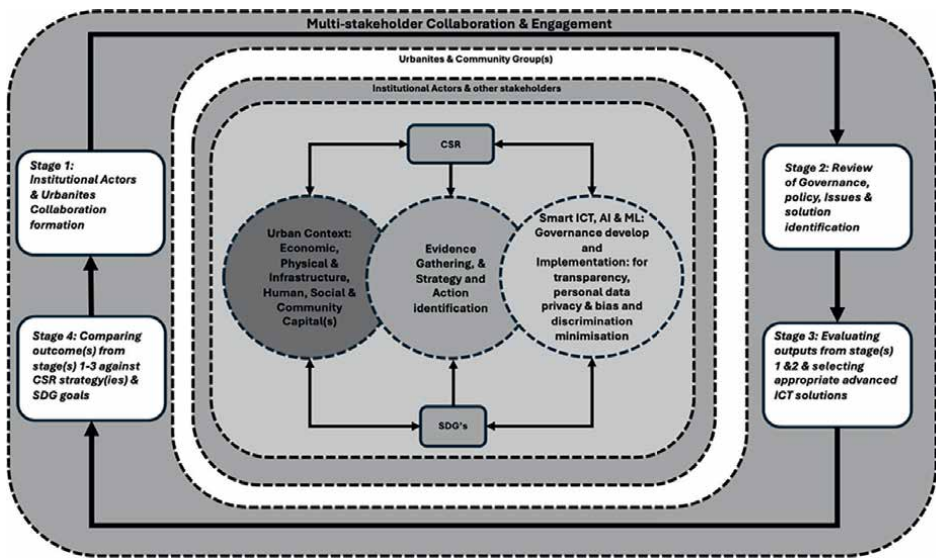


Figure 1.
Urban centric approach to smart city(ies).

the emphasis shifting from information sharing to collaboration and democratic debate on how urbanites perceive their most relevant urban problems and the concerns they have on the smart technological solutions, including AI and ML, that can be used to resolve them from their perspective across four asynchronous stage(s).

Beginning with *Stage (1)* Institutional actors and urbanites form collaborations (collaborative group(s)) to engage in democratic debate(s) to develop common understandings of urban problems and the smart technology(ies) issues for their urban locale(s) and leveraging the work from *Layer(s) 1 and 2* they agree on the potential linkages between these two areas and the institutional actors CSR and SDG strategy(ies). Progressing to *Stage (2)* the collaborative group(s) review the governance policy(ies) developed in *Layer 1* to agree on appropriate governance model(s) for the smart technology(ies) identified in *Stage 1*. Consideration is given to how different approaches contribute to ethical and transparent institutional actor(s) behaviours, personal data and information privacy and bias and discrimination minimisation. With a comparison taking place between what has emerged from *Stage(s) 1 and 2* in *Stage (3)* to ensure the smart technology(ies) identified improve urban economic, social, cultural and physical capital(s), and contribute towards the achievement of the good life for all urbanite(s) and direct institutional actors towards improving the CSR and SDG performance identified in *Layer 1*. If necessary, the process begins again until a pathway emerges that minimises the negative externality(ies). The process ends with *Stage (4)*. Wherein the collaborative groups asynchronously compare the outcomes from *Stage(s) 1–3* against the CSR and SDG strategy(ies) from *Layer 1* to identify the degree they align with all urbanite's expectations. Where misalignments occur, actions are agreed upon to extend the CSR and SDG strategy(ies) identified in *Stage 3* and to implement relevant performance measures to ensure that the smart technology(ies) selected enhance the social responsiveness of institutional actors, contribute to beneficial outcomes and a good life for all urbanites(s).

This approach has been adopted by Consolidated Land and Rail Australia's (CLARA) smart city(ies) project(s) [143]. CLARA intends to build eight compact smart city(ies) across the states of Victoria and New South Wales, connected via high-speed rail to Melbourne, Canberra and Sydney, to create a first of its kind network of smart city(ies) designed around the needs of urbanite(s). The site for their first smart city is Shepparton in Northern Victoria (CV2). Their smart city(ies) agenda(s) intends to put resident(s) and landscape before cars to enable CV2's urbanite(s) to feel happier, less isolated and become more active, by connecting them more naturally to each other, the natural environment, their region and surrounding capitals [144]. These projects will be funded by value capture rather than traditional models. In that the proceeds from the uplift in land values fund the establishment costs of new smart city(ies) [145]. Meaning that CLARA's smart city(ies) vision does not create a municipal government fiscal burden, nor a dependence on capital investment from large corporations. As such, CLARA has greater flexibility and freedom to adopt a more holistic, evolving and adaptive approach to their smart city(ies) development within the constraints of the needs of urbanite(s).

From inception, CLARA recognised that city(ies) are non-homogenous ecosystems with interwoven complex problems [74], that are best addressed by adopting an urbanite-centric, democratic and collaborative approach to problem identification and solution(s) selection ([14], pp. 136–139). A position driven by the CLARA's teams' passion for designing smart urban environments that address the needs, wants and aspiration of those who live within them and harness the power of smart

technology(ies) to create vibrant and thriving community(ies) [4, 9]. As such CLARA embraced the idea that urbanite(s), and community(ies) group(s), are central to their smart city(ies) agenda setting and decision making. With these points in mind the project team commenced the design of CV2 by working with government and large corporations to determine urban problem(s), identify possible strategic actions and smart technology(ies) that could address them and evaluate alternative governance models to maximise transparency and facilitate equal and equitable access for all (see **Figure 1**, Layer 1). This gave CLARA a foundational blueprint for broader stakeholder engagement.

The blueprint identified five strategic focus areas, that were considered most relevant to creating a liveable, vibrant and sustainable urban environment:- smart energy (e.g., solar, waste to energy and wind generation), integrated water management, urban mobility (e.g., mobility as a service and high-speed rail etc.), waste management (e.g., automatic vacuum waste disposal) and vibrant and authentic public place(s) [143]. To ensure that these areas best meet the needs of future resident(s) CLARA collaborated with a range of stakeholders (e.g., resident(s), NFP's, local government and the farming community(ies)) to debate, discuss and evaluate the five strategic focus areas and the proposed smart technology(ies) solution(s) (see **Figure 1**, Layer 2). All party(ies) were treated as equal partners and through democratic debate(s) whereby concerns were raised about the projects impact on cost of living, housing affordability, urban transportation and infrastructure needs [4]. To address these issues CLARA secured tentative commitment(s) from the large corporations (e.g., IBM and state government bodies etc.) to co-locate to CV2 and create employment opportunity(ies) for resident(s). Resulting in commitments to create over 45,000 new jobs during the construction phase, an additional 5000 to 10,000 jobs from US and Asia employment sponsors. CLARA also committed to building 334,000 affordable new smart home(s), located near business(es), to accommodate 801,000 residents in CV2 [145], and to a proposal that CV2 move away from private car ownership to mobility as a service, and electric autonomous vehicles use, to lower living costs and improve accessibility [143]. In essence, these proposal(s) led to an agreement on a range of viable economic and technological solution(s) that were seen as directly relevant to addressing the problems and needs of CV2's residents. At the time of writing, CLARA's team has begun multi-stakeholder engagement to finalise their smart city(ies) governance model, reach final agreement on the smart technology(ies) solutions and determine how to ensure best they meet the CSR and SDG's expectations of resident(s) (see **Figure 1**, Layer 3).

CLARA's funding model and their choice to adopt an urban-centric approach (see **Figure 1**) resolves the criticism(s) that smart city(ies) agendas are driven by large corporations such as IBM's etc., need for profit maximisation [64], and claims that their approach(s) fail to accommodate the diverse worlds and perspectives that exist for urbanite(s) [74]. By creating a democratic, inclusive and collaborative smart city(ies) project, CLARA's smart living project should result in a more vibrant, less disenfranchised, and more inclusive urban environment(s). In that by working closely with all stakeholders(s) they have been able to ensure that the needs, wants and aspirations of all residents, including non-mainstream community(ies) and urbanites from disadvantaged groups are taken into consideration across their smart city(ies) project(s) [4]. At present CLARA's smart city(ies) project has been tentatively approved by the Australian Government, albeit subject to the evaluation of alternative funding model(s) (e.g., value capture versus public-private partnerships). A process that has been delayed due to the COVID-19 pandemic. Yet, within

these constraints the team at CLARA is moving forward with further consultation with local community(ies) to ensure that any additional concerns are met before the construction phase commences. To some extent it remains to be seen whether CLARA's smart city(ies) will be as successful as claimed. Nevertheless, CLARA offers much promise for Australia and as a model for other countries smart city(ies) agendas. Particularly, CLARA's funding model and approach that simultaneously creates a financially viable smart city(ies) business model free from the constraints of large corporations and puts resident(s) at the centre of the decisions that are needed to ensure they live in an urban environment that meets their needs and aspirations for the good life within their urban locale(s).

6. Conclusion

This chapter demonstrated that smart city(ies) do offer urbanites the opportunity to pursue the good life within their urban environments. By showing that smart technology(ies) can increase economic and social opportunity(ies) [22, 24, 25], enhance urban environmental sustainability [26, 27, 33] and improve urbanites QoL [30, 58], wellbeing [49], and the liveability of community(ies) [4, 9, 27, 32]. Yet they do not do so for all urbanites. Rather, top-down decision making, one-sided perspective(s) on urban problems and techno-centric solutions to their resolution [61, 62, 64], and the primacy of institutional actors' interests create have and have not scenarios within urban community(ies) [8, 12, 63, 76] that create paradoxes for smart city(ies) agenda(s). In that they widen socio-economic and digital inequality(ies) [78–80, 82] and increase urbanites fears and anxiety(ies) about personal data and information privacy, transparency, bias and discrimination [98, 119] arising from increased AI adoption [95, 97, 106, 110]. Thus, creating a scenario(s) whereby not everyone gets access to the rights and opportunity(ies) associated with smart city(ies) living [9, 77], and by association the good life. Instead, the more educated, higher paid and skilled urbanites reap the benefits from smart city(ies) living and achieve a good life within their smart city(ies) [12, 78]. Whereas those from lower socio-economic and disadvantaged backgrounds are excluded, isolated and find their capacity for achieving the good life within smart city(ies) limited [62, 73, 81, 104, 123]. Leading to questions about the belief that smart technology(ies) alone can improve the lives of all urbanites [61] and to a viewpoint that the smart city(ies) agenda(s) is somehow flawed and detrimental to the lives of some urbanites [4, 9, 64, 66]. Building on our discussions an argument has been made for a fundamental re-orientation in the conceptualisation and design of smart city(ies). One where those responsible for smart city(ies) agendas recognise that smart technology(ies) alone cannot solve all urban problems [14, 61], and top-down techno-structural approaches will not improve the lives of all urbanites [62, 64] or facilitate the good life for all urbanites. A case was made for a more urbanite-centric [14, 65], democratic and collaborative approach to smart city(ies) decision making. One that puts urbanites in the driving seat in determining the shape, form, function and structure of their urban environments. Whilst granting them direct participation in the decision(s) concerning smart technology(ies) use within their community(ies). In essence, a process model was put forward (see **Figure 1**), with CLARA's smart city(ies) project(s) [143] used to illustrate its real-world application. A model that adopts an asynchronous and simultaneously multi-stakeholder perspective that emphasises CSR and SDGs [4, 133] to facilitate the pursuit of the good life for all urbanites.

Additional information

ORCID ID: 0000-0002-9230-365.

Author details

Andrew D. Roberts
Central Queensland University (CQU) Melbourne, Melbourne, Australia

*Address all correspondence to: a.d.roberts@cqu.edu.au

IntechOpen

© 2025 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. 

References

- [1] Leeson GW. The growth, ageing and urbanisation of our world. *Journal of Population Ageing*. 2018;**11**(2):107-115. DOI: 10.1007/s12062-018-9225-7
- [2] United Nations. World Urbanization Prospects: The 2011 Revision. New York: United Nations department of economic and social affairs/population division. UN Proceedings; 2012. Available from: https://www.un.org/en/development/desa/population/publications/pdf/urbanization/WUP2011_Report.pdf [Accessed: February 20, 2025]
- [3] Duranton G, Puga D. Urban growth and its aggregate implications. *Econometrica*. 2023;**91**(6):2219-2259. DOI: 10.3982/ECTA17936
- [4] Roberts AD. Corporate social responsibility (CSR): Governments, institutions, businesses, and the public within a smart city context. In: *Handbook of Smart Cities*. Switzerland: Springer; 2020. pp. 1-25. DOI: 10.1007/978-3-030-15145-4_30-1
- [5] Nijman J, Wei D. Urban inequalities in the 21st century economy. *Applied Geography*. 2020;**117**:102188. DOI: 10.1016/j.apgeog.2020.102188
- [6] Brooks MM. The changing landscape of affordable housing in the rural and urban United States, 1990-2016. *Rural Sociology*. 2022;**87**(2):511-546. DOI: 10.1111/ruso.12427
- [7] Zhang XQ. The trends, promises and challenges of urbanisation in the world. *Habitat International*. 2016;**54**:241-252. DOI: 10.1016/j.habitatint.2015.11.018
- [8] Kummitha RK, Crutzen N. How do we understand smart cities? An evolutionary perspective. *Cities*. 2017;**67**:43-52. DOI: 10.1016/j.cities.2017.04.010
- [9] Roberts AD. Smart City(ies): Citizen Equalisers or inequality generators. In: *Social Inequality-Structure and Social Processes*. London, UK: IntechOpen; 2023
- [10] Landry C. *The Creative City: A Toolkit for Urban Innovators*. New York: Routledge; 2012. DOI: 10.4324/978184
- [11] Kim Y, Warner ME. Pragmatic municipalism or austerity urbanism? Understanding local government responses to fiscal stress. *Local Government Studies*. 2021;**47**(2):234-252. DOI: 10.1080/03003930.2020.1729751
- [12] Caragliu A, Del Bo CF. Smart cities and urban inequality. *Regional Studies*. 2022;**56**(7):1097-1112. DOI: 10.1080/00343404.2021
- [13] Adams R. Longing for a greener present: Neoliberalism and the eco-city. *Radical Philosophy*. 2010;**163**(2):2-7. DOI: 10.1177/2043820614565748
- [14] Hollands RG. Will the real smart city please stand up? Intelligent, progressive or entrepreneurial? *City*. 2008;**12**(3):303-320. DOI: 10.1080/13604810802479126
- [15] Shamsuzzoha A, Nieminen J, Piya S, Rutledge K. Smart city for sustainable environment: A comparison of participatory strategies from Helsinki. Singapore and London. *Cities*. 2021;**114**:103194. DOI: 10.1016/j.cities.2021.103194
- [16] UN Department of Economic and Social Affairs Sustainable Development. 2025. Available from: <https://sdgs.un.org/> [Accessed: March 18, 2025]
- [17] Di Giullio A, Deffila R, Ruesch Schweizer C. Using the theory of

protected needs to conceptualize sustainability as ‘caring for human wellbeing’: An empirical confirmation of the theory’s potential. *Frontiers in Sustainability*. 2023;**4**:1036666. DOI: 10.3389/frsus.2023.1036666

[18] Frisch MB. Quality-of-life-inventory. In: *Nyclopedia of Quality of Life and Well-Being Research*. Cham: Springer International Publishing; 2024. pp. 5794-5797

[19] Luca SD. Preferring or needing cities? (evolutionary) psychology, utility and life satisfaction of urban living. *City, Culture and Society*. 2021;**24**:100375. DOI: 10.1016/j.ccs.2021.100375

[20] Pols J. *Reinventing the Good Life: An Empirical Contribution to the Philosophy of Care*. London: UCL Press; 2023

[21] Di Guilio A, Defila R. The ‘good life’ and protected needs. In: Kalfagianni A, Fuchs DA, Hayden A, editors. *Routledge Handbook of Global Sustainability Governance*. Abingdon: Routledge; 2020. pp. 100-114

[22] Myeong S, Park J, Lee M. Research models and methodologies on the Smart City: A systematic literature review. *Sustainability*. 2022;**14**:1687. DOI: 10.3390/su14031687

[23] Kumar V, Dahiya B. In: Kumar TMV, editor. *Smart Economy in Smart Cities*. Singapore: Springer; 2017. pp. 3-76

[24] Ammara U, Rasheed K, Mansoor A, Al-Fuqaha A, Qadir J. Smart cities from the perspective of systems. *Systems*. 2022;**10**:77. DOI: 10.3390/systems10030077

[25] Caragliu A, Del Bo CFD. Smart innovative cities: The impact of Smart City policies on urban innovation. *Technological Forecasting and*

Social Change. 2019;**142**:373-383. DOI: 10.1016/j.techfore.2018.07.022

[26] Weil C, Bibri SE, Longchamp R, Golay F, Alahi A. Urban digital twin challenges: A systematic review and perspectives for sustainable smart cities. *Sustainable Cities and Society*. 2023;**99**:104862. DOI: 10.1016/j.scs.2023.104862

[27] Ahmad RW, Salah K, Jayaraman R, et al Blockchain for waste management in smart cities: A survey. *IEEE Access*. 2021;**9**:131520-131541. DOI: 10.1109/ACCESS.2021.3113380

[28] De Guimarães JC, Severo EA, Júnior LA, Da Costa WP, Salmoria FT. Salmoria governance and quality of life in smart cities: Towards sustainable development goals. *Journal of Cleaner Production*. 2020;**253**:119926. DOI: 10.1016/j.clepro.2019.119926

[29] Murgante B, Borruso G. Smart cities in a smart world. In: Rassia S, Pardalos PM, editors. *Future City Architecture for Optimal Living*. Cham, UK: Springer; 2015. pp. 13-35

[30] Mishra KN, Chakraborty C. A novel approach toward enhancing the quality of life in smart cities using clouds and IoT-based technologies. In: *Digital Twin Technologies and Smart Cities*. Cham, Switzerland: Springer; 2020. pp. 19-35. DOI: 10.1007/978-3-030-18732-3_2

[31] Florida R, Mellander C, Rentfrow PJ. The happiness of cities. *Regional Studies*. 2013;**47**(4):613-627. DOI: 10.1080/0034304.2011.589830

[32] Bertram C, Rehdanz K. The role of urban green space for human well-being. *Ecological Economics*. 2015;**120**:139-152. DOI: 10.1016/j.ecolecon.2015.10.013

- [33] Ma X, Li J, Guo Z, Wan Z. Role of big data and technological advancements in monitoring and development of smart cities. *Heliyon*. 2024;**10**(15):1-14. DOI: 10.1016/j.heliyon.2024.e34821
- [34] Calvillo CF, S'anchez-Miralles A, Villar J. Energy management and planning in smart cities. *Renewable and Sustainable Energy Reviews*. 2016;**55**:273-287. DOI: 10.1016/j.rser.2015.10.133
- [35] De Oliveira LF, Manera LT, Da Luz PD. Development of a smart traffic light control system with real-time monitoring. *IEEE Internet of Things Journal*. 2020;**8**:3384-3393. DOI: 10.1109/JIOT.2020.3022392
- [36] Thakker S, Narayanamoorthi R. Smart and wireless waste management. In: 2015 International Conference on Innovations in Information, Embedded and Communication Systems (ICIIECS). California: IEEE; 2015. pp. 1-4. DOI: 10.1109/ICIIECS.2015.7193141
- [37] Catania V, Ventura D. An approach for monitoring and smart planning of urban solid waste management using smart-M3 platform. In: Proceedings of the 15th Conference of Open Innovations Association FRUCT. California: IEEE; 2014. pp. 24-31. DOI: 10.1109/FRUCT.2014.6872422
- [38] Etedadi Aliabadi F, Agbossou K, Kelouwani S, Henao N, Hosseini SS. Coordination of smart home energy management systems in neighborhood areas: A systematic review. *IEEE Access: Practical Innovations, Open Solutions*. 2021;**9**:36417-36443. DOI: 10.1109/ACCESS.2021.3061995
- [39] Piyare R, Tazil M. Bluetooth based home automation system using cell phone. In: 2011 IEEE 15th International Symposium on Consumer Electronics (ISCE). California: IEEE; 2011. pp. 192-195. DOI: 10.1109/ISCE.2011.5973811
- [40] Aguilar J, Garces-Jimenez A, R-moreno MD, García R. A systematic literature review on the use of artificial intelligence in energy self-management in smart buildings. *Renewable and Sustainable Energy Reviews*. 2021;**151**:111530. DOI: 10.1016/j.rser.2021.111530
- [41] Metallidou CK, Psannis KE, Egyptiadou EA. Energy efficiency in smart buildings: IoT approaches. *IEEE Access*. 2020;**8**:63679-63699. DOI: 10.1109/ACCESS.2020.2984461
- [42] Swords B, Coyle E, Norton B. An enterprise energy-information system. *Applied Energy*. 2008;**85**(1):61-69. DOI: 10.1016/j.apenergy.2007.06.009
- [43] Han MJ, Kim MJ. A critical review of the smart city in relation to citizen adoption towards sustainable smart living. *Habitat International*. 2021;**108**:102312. DOI: 10.1016/j.habitatint.2021.102312
- [44] Mouratidis K, Yiannakou A. What makes cities livable? Determinants of neighborhood satisfaction and neighborhood happiness in different contexts. *Land Use Policy*. 2022;**112**:105855. DOI: 10.1016/j.landusepol.2021.105855
- [45] Willard-Grace R, DeVore D, Chen EH, Hessler D, Bodenheimer T, Thom DH. The effectiveness of medical assistant health coaching for low-income patients with uncontrolled diabetes, hypertension, and hyper-lipidemia: Protocol for a randomized controlled trial and baseline characteristics of the study population. *BMC Family Practice*. 2013;**14**:27
- [46] Wang Y, Huang Y, Song C. A new smart sensing system using LoRaWAN

- for environment monitoring. In: 2019 Computing, Communications and IoT Applications (ComComAp). California: IEEE; 2019. pp. 347-351. DOI: 10.1109/ComComAp46287.2019.9018829
- [47] Hu J, Liang W, Hosam O, Hsieh MY, Su X. 5GSS: A framework for 5G-secure-smart healthcare monitoring. *Connection Science*. 2022;**34**(1):139-161. DOI: 10.1080/09540091.2021.1977243
- [48] Li D. 5G and intelligence medicine—How the next generation of wireless technology will reconstruct healthcare? *Precision Clinical Medicine*. 2019;**2**(4):205-208. DOI: 10.1093/pcmedi/pbz020
- [49] Mekuria DN, Sernani P, Falcionelli N, Dragoni AF. Smart home reasoning systems: A systematic literature review. *Journal of Ambient Intelligence and Humanized Computing*. 2021;**12**(4):4485-4502
- [50] Roberts AD. Smart cities, the internet of things (IoT's), and corporate social responsibility (CSR). In: *Machine Learning for Smart Environments/Cities: An IoT Approach*. Cham: Springer; 2022. pp. 127-148. DOI: 10.1007/978-3-030-97516-6_7
- [51] Syed L, Jabeen S, Manimala S, Alsaeedi A. Smart healthcare framework for ambient assisted living using IoMT and big data analytics techniques. *Future Generation Computer Systems*. 2019;**101**:136-151. DOI: 10.1016/j.future.2019.06.004
- [52] Javed AR, Fahad LG, Farhan AA, Abbas S, Srivastava G, Parizi RM, et al Automated cognitive health assessment in smart homes using machine learning. *Sustainable Cities and Society*. 2021;**65**:102572. DOI: 10.1016/j.scs.2020.102572
- [53] Kamruzzaman MM. New opportunities, challenges, and applications of edge-AI for connected healthcare in smart cities. In: 2021 IEEE Globecom Workshops (GC Wkshps). California: IEEE; 2021. pp. 1-6. DOI: 1109/GCWkshps52748.2021.9682055
- [54] Srihith IV, Kumar IV, Varaprasad R, Mohan YR, Srinivas TA, Sravanthi Y. Future of smart cities: The role of machine learning and artificial intelligence. *South Asian Research Journal of Engineering and Technology*. 2022;**4**(5):110-119. DOI: 10.36346/sarjet.2022.v04i05.005
- [55] Elwazer MN, Nessim AA. Integrating internet of things and big data as an approach for enhancing the quality of life in Egyptian cities. In: *IOP Conference Series: Earth and Environmental Science*. Vol. 1396, No. 1. England: IOP Publishing; 2024. p. 012027. DOI: 10.1088/1755-1315/1396/1/012027
- [56] Caragliu A, Del Bo C, Nijkamp P. Smart cities in Europe. *Journal of Urban Technology*. 2011;**18**(2):65e82. DOI: 10.10630732.2011.601117
- [57] McKinsey Global Institute. Smart cities: digital solutions for a more livable future. New York: McKinsey Global Institute; 2018. Available from: <https://www.mckinsey.com/~media/mckinsey/business%20functions/operations/our%20insights/smart%20cities%20digital%20solutions%20for%20a%20more%20livable%20future/mgi-smart-cities-full-report.pdf> [Accessed: March 29, 2025]
- [58] Yu C, Ye B, Lin C, Wu YJ. Can Smart City development promote residents' emotional well-being? Evidence from China. *IEEE Access*. 2020;**8**:116024-116040. DOI: 10.1109/ACCESS.2020.3004367

- [59] Capdevila I, Zarlenga MI. 2015. Smart city or smart citizens? The Barcelona case. *Journal of Strategy and Management*. 2015;8(3):266-282. DOI: 10.1108/J SMA-03-2015-0030
- [60] Shichiyakh RA, Klyuchnikov DA, Balashova SP, Novoselov SN, Novosyolova NN. Smart City as the basic construct of the socio-economic development of territories. *International Journal of Economics and Finance Issues*. 2016;6(1):157-162
- [61] Yigitcanlar T, Kamruzzaman M, Foth M, Sabatini-Marques J, Da Costa E, Ioppolo G. Can cities become smart without being sustainable? A systematic review of the literature. *Sustainable Cities and Society*. 2019;45:348-365. DOI: 10.1016/j.scs.2018.11.033
- [62] Cugurullo F. How to build a sandcastle: An analysis of the genesis and development of Masdar City. *Journal of Urban Technology*. 2013;20(1):23-37
- [63] Lee JY, Woods O, Kong L. Towards more inclusive smart cities: Reconciling the divergent realities of data and discourse at the margins. *Geography*. 2020;14:e12504
- [64] Angelidou M. Smart cities: A conjuncture of four forces. *Cities*. 2015;47:95-106. DOI: 10.1016/j.cities.2015.05.004
- [65] Hollands RG. Critical interventions into the corporate smart city. *Cambridge Journal of Regions, Economy and Society*. 2015;8(1):61-77. DOI: 10.1093/cjres/rsu011
- [66] Townsend AM. *Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia*. New York: WW Norton & Company; 2013
- [67] Hu MC, Wu CY, Shih T. Creating a new socio-technical regime in China: Evidence from the Sino-Singapore Tianjin Eco-City. *Futures*. 2015;70:1-12. DOI: 10.1016/j.futures.2015.04.001
- [68] Yigitcanlar T. *Technology and the City: Systems, Applications and Implications*. London: Routledge; 2016. DOI: 10.4324/9781315739090
- [69] Yigitcanlar T, Lee S. Korean ubiquitous-eco-city: A smart-sustainable urban form or a branding hoax? *Technological Forecasting and Social Change*. 2014;89:100-114. DOI: 10.1016/j.techfore.2013.08.034
- [70] Yigitcanlar T, Kamruzzaman M, Buys L, Ioppolo G, Sabatini Marques J, da Costa EM, et al Understanding 'smart cities': Intertwining development drivers with desired outcomes in a multidimensional framework. *Cities*. 2018;81:145-160. DOI: 10.1016/j.cities.2018.04.003
- [71] Kunzmann KR. Smart cities: A new paradigm of urban development. *Crios*. 2014;1:9-20. DOI: 10.7373/77140
- [72] IBM. What Is a Smart City? New York: IBM; 2023. Available from: <https://www.ibm.com/think/topics/smart-city> [Accessed: April 8, 2025]
- [73] Cowley R, Joss S, Dayot Y. The smart city and its publics: Insights from across six UK cities. *Urban Research & Practice*. 2018;11(1):53-77. DOI: 10.1080/17535069
- [74] Söderström O, Paasche T, Klauser F. Smart cities as corporate storytelling. In: *The Routledge Companion to Smart Cities*. London: Routledge; 2020. pp. 283-300
- [75] Robinson C, Franklin RS. The sensor desert quandary: What does it mean (not) to count in the smart city? *Transactions of the Institute of British*

Geographers. 2021;**46**(2):238-254.
DOI: 10.1111/tran.12415

[76] Caragliu A, Del Bo CF. Smart cities and the urban digital divide. *Npj Urban Sustainability*. 2023;**3**(1):43.
DOI: 10.1038/s42949-023-00117-w

[77] Saraceni G. Informational opulence, digital divide and poverty. *Humanities and Rights Global Network Journal*. 2021;**3**(2):1-20. DOI: 10.24861/2675-1038.v3i2.72

[78] Yang Z, Gao W, Han Q, Qi L. Aggravating or alleviating? Smart city construction and urban inequality in China. *Technology in Society*. 2024;**77**:102562. DOI: 10.1016/j.techsoc.2024.102562

[79] Foley RW, Nadjari S, Eshirrow J, Adekunle R, Codjoe P. Towards digital segregation? Problematizing the haves and have nots in the smart city. *Frontiers in Sustainable Cities*. 2022;**4**:706670. DOI: 10.3389/frsc.2022.706670

[80] Raihan MM, Subroto S, Chowdhury N, Koch K, Ruttan E, Turin TC. Dimensions and barriers for digital (in) equity and digital divide: A systematic integrative review. *Digital Transformation and Society*. 2025;**4**(2):111-127. DOI: 10.1108/DTS-04-2024-0054

[81] Kitchin R, Cardullo P, Di Felicianantonio C. Citizenship, justice, and the right to the smart city. In: *The Right to the Smart City*. West Yorkshire: Emerald Publishing Limited; 2019

[82] Calzada I, Pérez-Batlle M, Batlle-Montserrat J. People-centered smart cities: An exploratory action research on the cities' Coalition for Digital Rights. *Journal of Urban Affairs*. 2023;**45**:1537-1562. DOI: 10.1080/07352166.2021.1994861

[83] Richmond K, Triplett RE. ICT and income inequality: A cross-national perspective. *International Review of Applied Economics*. 2018;**32**(2):195-214. DOI: 10.1080/02692171.2017.1338677

[84] OECD. Aging. France: OECD; 2023. Available from: <https://www.oecd.org/en/topics/policyissues/ageing.html#:~:text=Context-,Population%20ageing,on%20average%20across%20OECD%20countries> [Accessed: April 13, 2025]

[85] Van Dijk JA. *The Deepening Divide: Inequality in the Information Society*. California: Sage publications; 2005

[86] Chib A, Alvarez K, Todorovic T. Critical perspectives on the smart city: Efficiency objectives vs inclusion ideals. *Journal of Urban Technology*. 2022;**29**(4):83-99. DOI: 10.1080/10630732.2021.2001712

[87] Reddick C, Enriquez R, Harris R, Flores J. Understanding the levels of digital inequality within the city: An analysis of a survey. *Cities*. 2024;**148**:104844. DOI: 10.1016/j.cities.2024.104844

[88] Bleja J, Langer H, Grossmann U, Mörz E. Smart cities for everyone—age and gender as potential exclusion factors. In: *2020 IEEE European Technology and Engineering Management Summit (E-TEMS)*. California: IEEE; 2020. pp. 1-5. DOI: 10.1109/E-TEMS46250.2020.9111741

[89] Mohan R, Saleem F, Voderhobli K, Sheikh-Akbari A. Ensuring sustainable digital inclusion among the elderly: A comprehensive analysis. *Sustainability*. 2024;**16**(17):7485. DOI: 10.3390/su16177485

[90] Wang CH, Steinfeld E, Maisel JL, Kang B. Is your smart city inclusive?

- Evaluating proposals from the US Department of Transportation's Smart City challenge. *Sustainable Cities and Society*. 2021;**74**:103148. DOI: 10.1016/j.scs.2021.103148
- [91] Ahad MA, Paiva S, Tripathi G, Feroz N. Enabling technologies and sustainable smart cities. *Sustainable cities and society*. 2020;**61**:102301. DOI: 10.1016/j.scs.2020.102301
- [92] Agnew JA. Slums, ghettos, and urban marginality. *Urban Geography*. 2010;**31**(2):144-147. DOI: 10.2747/0272-3638.31.2.144
- [93] Alloulbi A, Oz T, Alzubi A. The use of artificial intelligence for smart decision-making in smart cities: A moderated mediated model of technology anxiety and internal threats of IoT. *Mathematical Problems in Engineering*. 2022;**2022**:1-12. DOI: 10.1155/2022/6707431
- [94] Bibri SE, Krogstie J, Kaboli A, Alahi A. Smarter eco-cities and their leading-edge artificial intelligence of things solutions for environmental sustainability: A comprehensive systematic review. *Environmental Science and Ecotechnology*. 2024;**19**:100330. DOI: 10.1016/j.jese.2023.100330
- [95] Perrault R, Jack C. Artificial Intelligence Index Report. 2024. Available from: https://hai-production.s3.amazonaws.com/files/hai_ai-index-report-2024-smaller2.pdf [Accessed: March 10, 2025]
- [96] Brynjolfsson E, McAfee A. *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*. New York: WW Norton & Company; 2014
- [97] Zhang P. Automation, wage inequality and implications of a robot tax. *International Review of Economics & Finance*. 2019;**59**:500-509. DOI: 10.1016/j.iref.2018.10.013
- [98] Jin GZ. Artificial intelligence and consumer privacy. *National Bureau of Economic Research*. 2018:439-462. DOI: 10.3386/w24253
- [99] Tucker C, Agrawal A, Gans J, Goldfarb A. Privacy, algorithms, and artificial intelligence. In: *The Economics of Artificial Intelligence: An Agenda*. Chicago, IL: University of Chicago Press; 2018. pp. 423-437
- [100] Goyal A, Aneja R. Artificial intelligence and income inequality: Do technological changes and worker's position matter? *Journal of Public Affairs*. 2020;**20**(4):e2326. DOI: 10.1002/pa.2326
- [101] Graetz G, Michaels G. Robots at work. *Review of Economics and Statistics*. 2018;**100**(5):753-768. DOI: 10.1162/rest_a_00754
- [102] CEA. 2016 Economic Report of the President. Washington DC: Council of Economic Advisers; 2016. Available from: <https://obamawhitehouse.archives.gov/administration/eop/cea/economic-report-of-the-President/2016> [Accessed: April 10, 2025]
- [103] Arntz M, Gregory T, Zierahn U. *The Risk of Automation for Jobs in OECD Countries: A Comparative Analysis*. France: OECD Publishing; 2016. DOI: 10.1787/5jlz9h56dvq7-en
- [104] Lim S, Malek JA, Hussain MY, Tahir Z. Citizen participation in building citizen-centric smart cities. *Malaysian Journal of Society and Space*. 2018;**14**(4):42-53. DOI: 10.17576/geo-2018-1404-04
- [105] Lehtiö A, Hartikainen M, Ala-Luopa S, Olsson T, Väänänen K. Understanding citizen perceptions

of AI in the smart city. *Ai & Society*. 2023;**38**(3):1123-1134. DOI: 10.1007/s00146-022-01589-7

[106] Savela N, Latikka R, Lahtinen J, Oksanen A. Robots are coming to town: A visual experiment on urban belonging and anxiety. *Cities*. 2024;**144**:104640. DOI: 10.1016/j.cities.2023.104640

[107] Zimmerman A, Janhonen J, Beer E. Human/AI relationships: Challenges, downsides, and impacts on human/human relationships. *AI and Ethics*. 2024;**4**(4):1555-1567. DOI: 10.1007/s43681-023-00348-8

[108] Guignon C. Identity, history, tradition. In: *A Companion to Hermeneutics*. Hoboken, NJ, USA: Wiley; 2015. pp. 130-143. DOI: 10.1002/9781118529812.ch14

[109] Gattino S, De Piccoli N, Fassio O, Rollero C. Quality of life and sense of community. A study on health and place of residence. *Journal of Community Psychology*. 2013;**41**(7):811-826. DOI: 10.1002/jcop.21575

[110] Kim JJ, Soh J, Kadkol S, Solomon I, Yeh H, Srivatsa AV, et al AI anxiety: A comprehensive analysis of psychological factors and interventions. *AI and Ethics*. 2025:1-7. DOI: 10.1007/s43681-025-00686-9

[111] Goldstein J. Australian Police Are Using the Clearview AI Facial Recognition System with No Accountability. Melbourne, Australia: The Conversation; 2020. Available from: <https://theconversation.com/australian-police-are-using-the-clearview-ai-facial-recognition-system-with-no-accountability-132667> [Accessed: March 11, 2025]

[112] Mortenson WB, Sixsmith A, Woolrych R. The power (s) of

observation: Theoretical perspectives on surveillance technologies and older people. *Ageing & Society*. 2015;**35**(3):512-530. DOI: 10.1017/S0144686X13000846

[113] Correia L, Wünstel K. Smart Cities Applications and Requirements. White Paper of Experts Working Group Net! Brussels, Belgium: Works European Technology Platform; 2011. Available from: https://grow.tecnico.ulisboa.pt/wpcontent/uploads/2014/03/White_Paper_Smart_Cities_Applications [Accessed: April 10, 2025]

[114] Nam T, Pardo TA. Conceptualizing smart city with dimensions of technology, people, and institutions. In: *Proceedings of the 12th Annual International Digital Government Research Conference: Digital Government Innovation in Challenging Times*. New York: University of Albany; 2011. pp. 282-291. DOI: 10.1145/2037556.2037602

[115] Kosinski M, Stillwell D, Graepel T. Private traits and attributes are predictable from digital records of human behavior. *National Academy of Sciences of the United States of America*. 2013;**110**(15):5802-5805. DOI: 10.1073/pnas.1218772110

[116] David E, Zhitomirsky-Geffet M, Koppel M, Uzan H. Utilizing Facebook pages of the political parties to automatically predict the political orientation of Facebook users. *Online Information Review*. 2016;**40**(5):610-623. DOI: 10.1108/OIR-09-2015-0308

[117] Wang Y, Kosinski M. Deep neural networks are more accurate than humans at detecting sexual orientation from facial images. *Journal of Personality and Social Psychology*. 2018;**114**(2):246. DOI: 10.1037/pspa0000098

- [118] Marciano A, Antebi-Gruszka N. Offline and online discrimination and mental distress among lesbian, gay, and bisexual individuals: The moderating effect of LGBTQ Facebook use. *Media Psychology*. 2022;**25**(1):27-50. DOI: 10.1080/15213269.2020.1850295
- [119] Menard P, Bott GJ. Artificial intelligence misuse and concern for information privacy: New construct validation and future directions. *Information Systems Journal*. 2025;**35**(1):322-367. DOI: 10.1111/isj.12544
- [120] Sawhney N. Contestations in urban mobility: Rights, risks, and responsibilities for urban AI. *AI & Society*. 2023;**38**(3):1083-1098. DOI: 10.1007/s00146-022-01502-2
- [121] Willems J, Schmid MJ, Vanderelst D, Vogel D, Ebinger F. AI-driven public services and the privacy paradox: Do citizens really care about their privacy? *Public Management Review*. 2023;**25**(11):2116-2134. DOI: 10.1080/14719037.2022.2063934
- [122] Singh S, Sharma PK, Yoon B, Shojafar M, Cho GH, Ra IH. Convergence of blockchain and artificial intelligence in IoT network for the sustainable smart city. *Sustainable Cities and Society*. 2020;**63**:102364. DOI: 10.1016/j.scs.2020.102364
- [123] Zhang B, Dafoe A. Artificial intelligence: American attitudes and trends. *SSRN Electronic Journal*. 2019:1-111. DOI: 10.2139/ssrn.3312874
- [124] DeCanio SJ. Robots and humans—complements or substitutes? *Journal of Macroeconomics*. 2016;**49**:280-291. DOI: 10.1016/j.jmacro.2016.08.003
- [125] Zhou Y, Tyers R. Automation and inequality in China. *China Economic Review*. 2019;**58**:101202. DOI: 10.1016/j.chieco.2018.07.008
- [126] Greenfield A. *Against the Smart City*. New York: Do Publications; 2013
- [127] Kitchin R. The real-time city? Big data and smart urbanism. *GeoJournal*. 2014;**79**:1-4. DOI: 10.1007/s10708-013-9516-8
- [128] Biloría N. From smart to empathic cities. *Frontiers of Architectural Research*. 2021;**10**(1):3-16. DOI: 10.1016/j.foar.2020.10.001
- [129] Carroll AB. A three-dimensional conceptual model of corporate performance. *Academy of Management Review*. 1979;**4**(4):497-505. DOI: 10.5465/1mr.1979.4498296
- [130] Crane A, Palazzo G, Spence LJ, Matten D. Contesting the value of “creating shared value”. *California Management Review*. 2014;**56**(2):130-153. DOI: 10.1525/cmr.2014.56.2.13
- [131] Wood DJ. Measuring corporate social performance: A review. *International Journal of Management Reviews*. 2010;**12**(1):50-84. DOI: 10.1111/j.1468-2370.2009.00274.x
- [132] United Nations (UN). *Sustainable Development Goals*. New York: United Nations (UN); 2022. Available from: <https://sdgs.un.org/goals> [Accessed: March 1, 2025]
- [133] Khaled R, Ali H, Mohamed EK. The sustainable development goals and corporate sustainability performance: Mapping, extent and determinants. *Journal of Cleaner Production*. 2021;**311**:127599. DOI: 10.1016/j.jclepro.2021.127599
- [134] Global Reporting Initiative (GRI). *State of Progress: Business Contributions*

to the SDGS, a 2020-2021 Study in Support of the Sustainable Development Goals. Amsterdam: Global Reporting Initiative (GRI); 2021. Available from: <https://www.globalreporting.org/media/ab5lun0h/stg-gri-report-final.pdf> [Accessed: March 1, 2025]

[135] Ramos DL, Chen S, Rabeeu A, Abdul Rahim AB. Does SDG coverage influence firm performance? Sustainability. 2022;**14**(9):4870. DOI: 10.3390/su14094870

[136] Cao H, Kang CI. A citizen participation model for co-creation of public value in a smart city. Journal of Urban Affairs. 2024;**46**(5):905-924. DOI: 10.1080/07352166.2022.2094799

[137] Leclercq EM, Rijshouwer EA. Enabling citizens' right to the Smart City through the co-creation of digital platforms. Urban Transformations. 2022;**4**(1):2. DOI: 10.1186/s42854-022-00030-y

[138] Przybilowicz E, Cunha MA, Geertman S, Leleux C, Michels A, Tomor Z, et al Citizen participation in the smart city: Findings from an international comparative study. Local Government Studies. 2022;**48**(1):23-47. DOI: 10.1080/03003930.2020.1851204

[139] Beck D, Ferasso M, Storopoli J, Vigoda-Gadot E. Achieving the sustainable development goals through stakeholder value creation: Building up smart sustainable cities and communities. Journal of Cleaner Production. 2023;**399**:136501. DOI: 10.1016/j.clepro.2023.136501

[140] Carroll AB, Brown J, Buchholtz AK. Business & Society: Ethics, Sustainability & Stakeholder Management. 2nd ed. Mason: Cengage; 2017

[141] Harvey D. From managerialism to entrepreneurialism: The transformation

in urban governance in late capitalism. Geografiska Annaler: Series B, Human Geography. 1989;**71**(1):3-17. DOI: 10.1080/04353684.1989.11879583

[142] Brenner N, Theodore N. Preface: From the "new localism" to the spaces of neoliberalism. Antipode. 2002;**34**(3):341-347

[143] Consolidated Land and Rail Australia (CLARA). 2025. Available from: <https://www.clara.com.au/> [Accessed: May 26, 2025]

[144] Clarke Hopkins Clarke. CLARA 8 Smart Cities Connected by High-Speed Rail. Available from: <https://www.chc.com.au/project/clara> [Accessed: May 26, 2025]

[145] Busnell I. High-Speed Rail: Consortium Plans New Inland Cities to Support Melbourne-Canberra-Sydney Network. Available from: <https://region.com.au/high-speed-rail-consortium-plans-new-inland-cities-to-support-melbourne-canberra-sydney-network/221036/> [Accessed: May 26, 2025]

Chapter 3

The Rise of the Smartivist: From Creative Class to Citizen-Centric Smart Sustainable Cities

Bart Gorynski

Abstract

The concept of the Creative Class, introduced by Richard Florida in the early 2000s, has significantly influenced post-industrial urban development theory. To maintain economic competitiveness, urban policy shifted toward attracting highly skilled, idea-driven individuals by focusing on talent, location quality, and cultural vitality. This chapter critically examines the evolution, influence, and limitations of the Creative Class, as well as the necessity and role of creativity in a digitalized urban landscape. In response to technological acceleration, social inequalities, and calls for stronger civic engagement, this chapter traces the conceptual shift from the Creative Class to the Smartivist, a smart sustainable city activist, a digitally empowered and socially committed actor who portrays the convergence of creativity, technology, and participatory governance in the era of the Smart City. Through theoretical grounding and international case studies, the chapter introduces the Smartivist as a new urban changemaker who drives innovation and co-produces inclusive, resilient, and democratically embedded urban futures. Drawing on sources such as *bee smart city*, the study argues that the rise of the Smartivist marks a paradigm shift from cultural capital to civic capital, placing collective intelligence and digital citizenship at the heart of equitable city-making. The chapter explores the origins and transformation of the Creative Class, the transition to the Smartivist, and the latter's active engagement in shaping urban life through digital and civic means. It concludes with practical guidance on how cities can support these citizen innovators to foster trust and promote inclusive urban development.

Keywords: Creative Class, Smart Cities, Smartivist, digital citizenship, civic engagement, urban innovation, participatory governance, technological citizenship, urban transformation, collective intelligence, digital participation, cultural capital, civic capital, civic tech, citizen-centric Smart Cities

1. Introduction

Since its publication in 2002, “The Rise of the Creative Class” has become a key element in debates about urban growth and economic competitiveness. According to

the author Richard Florida, the new economic era is defined by a class of workers that create ideas, technologies, and content as their primary economic function. In this so-called “creative age,” the specific class of workers is represented by knowledge-based professionals. It is the era of scientists, artists, designers, engineers, and educators [1]. Florida distinguishes between a “super-creative core” and “creative professionals,” yet both groups are united by their ability to generate innovation and solve complex problems through cognitive labor.

Florida’s thesis introduced a people- and place-centric development model, wherein cities succeed by attracting talented individuals rather than simply courting businesses. This shift in focus from firm-centered to human-centered economic development aligned with earlier theories of human capital, as advanced by scholars like Becker and Lucas [2, 3]. However, Florida’s theory innovated by incorporating qualitative factors such as urban vibrancy, cultural amenities, and tolerance. These became critical in his “3T” framework: Technology, Talent, and Tolerance [1].

The Creative Class framework resonated strongly with urban planners and policy-makers, catalyzing a wave of city branding, cultural investment, and urban regeneration strategies aimed at attracting highly skilled, innovation-oriented individuals. In this context, a range of indicators, such as the Bohemian Index, the Diversity Index, or the prevalence of cultural and educational institutions, emerged as proxies for the open, tolerant, and vibrant urban environments believed to foster creativity and economic dynamism [1, 4]. Pratt criticized, however, that these indices often conflated creative production with creative consumption, leading to oversimplified urban policy approaches [4].

In the 2000s, cities across North America, Europe, and Asia adopted policies aimed at cultivating the conditions described by Florida—bike lanes, galleries, music venues, coworking spaces—sometimes to the point of mimicry.

However, the Creative Class thesis has faced significant critique. Peck, in his landmark paper *Struggling with the Creative Class*, argued that the framework functioned more as a seductive narrative for urban elites than a rigorous analytical tool [5]. Peck contended that Florida’s theory masked underlying neoliberal policy agendas, promoted gentrification, and ignored labor market inequalities. Similarly, Pratt highlighted that the Creative Class model failed to distinguish sufficiently between structural economic drivers and cultural trends, and often overstated the causal link between creative clustering and economic growth [4].

Despite these critiques, the concept evolved. Florida himself addressed shortcomings in *The New Urban Crisis*, acknowledging that the clustering of talent could exacerbate inequality and displacement. He called for more inclusive strategies that extend the benefits of creative economies to broader populations [6].

Simultaneously, the concept of creativity in urban development was shifting. The rapid growth of digital technology, remote work, and online platforms transformed how and where creative work happens. New digital roles like UX designers, data scientists, and app developers blurred the line between culture and tech [7]. Cities began to invest in digital infrastructure and smart technologies, linking the Creative Class concept to the emerging Smart City discourse. Evans and Karvonen describe urban living labs as experimental environments where digital creativity and civic innovation intersect—offering new contexts for the evolution of urban creative roles [8].

2. From Creative Class to Smartivist: The citizen-driven evolution of the Smart City

In order to understand the step from the Creative Class to the Smartivist, we first need to take a closer look at the development of the concept of the smart sustainable city and the influence of the Creative Class on it. The main reason for the shift to the Smartivist was that rapid technological developments in urban planning initially left out a key stakeholder: the citizen.

2.1 From Smart City 1.0 to a Smart Sustainable City 4.0

Simplified Smart City is an ecosystem of solutions (technical), initiatives (non-technical), and processes. A Smart City is not a static concept but a dynamic development process shaped by time, technology, and people. While it was strongly technology-driven and dominated by tech corporations at the turn of the millennium, the concept has since evolved into a citizen-centric, locally co-created strategy increasingly guided by public administrations (**Figure 1**) [10].

At the heart of this evolution lies a continuous dialog with residents.

Moreover, the Smart City has grown into a multi-layered concept that operates on various levels: from Smart Nations and Smart Cities to Smart Regions, Smart Districts and Neighborhoods, Smart Buildings, Smart Spaces and Infrastructure, and Smart Homes and Workplaces (**Figure 2**) [9].

Smart Cities and Smart Regions are closely linked to public services, aiming to make essential public functions more efficient, sustainable, and user-friendly within the six key dimensions of Smart Cities (**Figure 3**) [11].

In this transformation process, digital public services play a key role in enhancing and modernizing classical infrastructure and utilities through technological innovation [12].

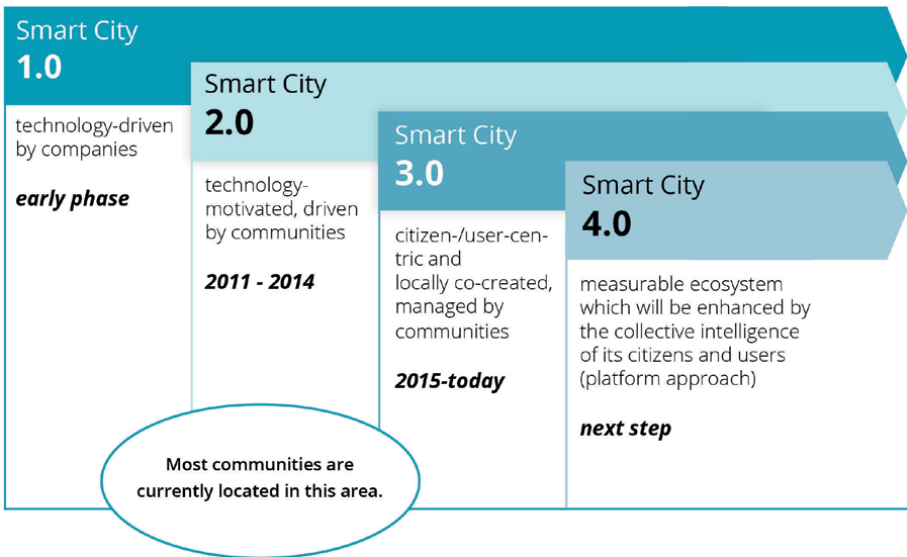


Figure 1.
The evolution of the Smart City concept from technology-driven 1.0 models to participatory, citizen-centered Smart City 4.0 approaches, illustrated by bee smart city [9].



Figure 2.
The multi-layered structure of Smart Cities and Regions, from national strategies to individual living and working environments, illustrated by bee smart city [9], updated version.

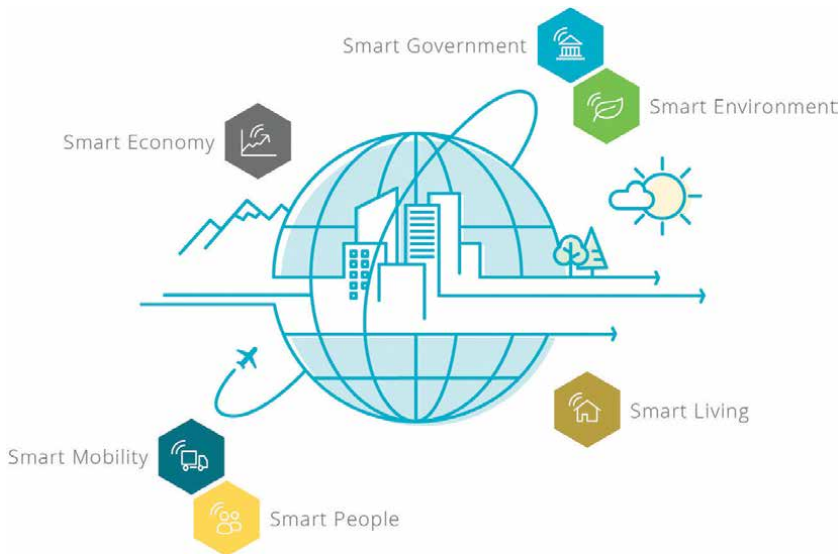


Figure 3.
The six key dimensions of Smart Cities as interconnected elements of a holistic urban system by R. Giffinger; illustrated by bee smart city [9].

While traditional public services cover areas such as utilities, mobility, social and cultural services, safety and health, finance, and public communication, Smart Cities and Smart Regions add a new, overarching pillar: digital public services. This new layer permeates all existing structures and becomes a central driver of digital transformation in public service delivery.

2.1.1 Moving from technology-driven to citizen-centric and locally co-created

The Smart City Movement emerged in the late 2000s and early 2010s as a necessary response to increasing urban complexity and resource scarcity, both calling for real-time governance. At first glance, these seemed to be only technological issues. Therefore, the early Smart City model focused on technological infrastructure as well as data-driven systems and operational efficiency, instead of cultural capital, individual talent, and human-centered economic development [13]. Due to this fixated view on the technological and data-driven aspects, tech corporations like IBM, Cisco, and Siemens dominated the general discourse. They soon offered centralized platforms to optimize urban infrastructure like traffic, energy, security, and other services.

However, these visions and approaches have since faced growing criticism for their top-down approach and lack of citizen involvement. This led to concerns about civil surveillance, data privacy and data security, and democratic legitimacy. As a result, the discourse began to shift toward more human-centered, participatory models [14].

In this evolving context, a new definition of Smart Cities emerged—one that balances technological innovation with social inclusion. As outlined by the smart city in *Toward a New Smart City Definition*, the term “smart” now encompasses not only just efficiency and automation, but also equity, resilience, and community empowerment [15].

This more holistic vision not only aligns with the values of the Creative Class while also expanding them by integrating civic responsibility, digital empowerment, and collaborative governance.

The transition from a Creative Class-driven urban paradigm to a citizen-centered Smart City model signifies more than technological progress. It reflects a deeper philosophical shift: from cities designed to attract creative individuals toward cities designed to activate their potential through digital participation, co-creation, and inclusive innovation [16].

At the intersection of technology, civic engagement, and urban creativity, a new urban changemaker is emerging: the Smartivist.

3. The rise of the Smartivist

The Smartivist, a smart sustainable city activist, is the civic evolution of the Creative Class: a digitally fluent, socially conscious urban innovator who not only produces creative and economic value but also contributes actively to shaping inclusive, participatory, and resilient cities. Where the Creative Class emphasized cultural capital and individual talent as drivers of urban growth, the Smartivist embodies collective intelligence and digital empowerment as tools for civic transformation.

The Smartivist reflects the idea of a “technological citizen” by Feenstra and Keane [16] and is therefore closely related to “digital citizenship,” a concept outlined by Mossberg, Tolbert and McNeal [17]. The “technological citizen” is characterized as an urban actor

who no longer only acts as a consumer of digital services but also co-produces public value through real-time interactions with digital infrastructures [16]. The concept of “digital citizenship” provides equal access, digital skills, and civic engagement as the base of participatory democracy in a connected society [17]. As the Smart City paradigm matured, it became increasingly clear that smart infrastructure alone does not make a city truly intelligent. The most effective Smart Cities are those that not only utilize technology but also their citizens creative capacities. This realization highlighted the gap that is now occupied by the concept of the Smartivist: a digitally literate, civically engaged individual who actively contributes to the co-creation of smarter urban environments.

According to bee smart city, the Smartivist represents a new generation of urban innovators who combine the values of the Creative Class with a deep commitment to public good [15]. Unlike traditional creatives who might focus on economic or artistic outputs, Smartivists apply their skills to solve civic challenges—developing open-data applications, participating in urban design workshops, or launching grassroots sustainability initiatives.

The Smartivist is characterized by five core attributes:

- Digital fluency—The ability to use digital tools to analyze problems, mobilize communities, and implement solutions.
- Civic engagement—A commitment to participation in local governance, often through digital platforms such as participatory budgeting or urban hackathons.
- Collaborative mindset—A preference for open innovation and cross-sector partnerships.
- Place-based loyalty—An investment in the social, cultural, and environmental health of one’s community.
- Systems thinking—The ability to connect urban problems across domains and act within complex civic ecosystems.

In Smartivist Accelerate Smart City Development, bee smart city highlights how Smartivists act as catalysts for innovation, often bridging the gap between city governments, private firms, and civil society [18]. They embody the principle that Smart Cities should be for the people and by the people. Their rise also coincides with the proliferation of civic tech-tools and platforms that facilitate citizen input, data transparency, and collaborative problem-solving [19].

Importantly, the Smartivist is not a solitary figure. Their strength emerges from being embedded in networked structures. Smartivists form communities of practice that share knowledge, code, and strategies across cities and continents. Through this collective engagement, they become a vital resource for local governments seeking to implement responsive and adaptive urban policies.

The Smartivist also reflects the digitalization of urban citizenship. Whereas the Creative Class operated primarily within professional and cultural domains, the Smartivist operates in hybrid spaces at the intersection of technology, governance, and community. Their agency is hybrid: Smartivists operate across roles as voters, developers, designers, critics, and co-implementers. Their activism is both online and offline, and their impact is measured not just in GDP, but in community resilience, social inclusion, and democratic renewal [18, 19].

This reconceptualization of the urban innovator has profound implications for city planning and policy. It suggests that the future of Smart Cities requires both infrastructure and investment, as well as on empowerment. Cities must create enabling environments where Smartivists can thrive. They can achieve such an environment through open data policies, micro-grants, innovation labs, and inclusive governance structures [19].

In summary, the Smartivist is the logical successor to the Creative Class in a digitized, networked world. They retain the Creative Class's emphasis on autonomy, innovation, and expression, but apply these traits toward civic rather than purely economic goals. They represent the next step in the evolution of urban development theory—one that places the digitally empowered citizen at the heart of the Smart City.

The transition from a Creative Class to Smartivists can also be viewed as a shift from cultural capital to civic capital. In contrast to the Creative Class, the Smartivist focuses on infrastructural openness, access to decision-making, and data co-creation. The Creative Class, on the other hand, is centered around symbolic indicators of creative openness like galleries, design clusters, and a lively nightlife. Ultimately, Civic Capital refers to the ability of residents to actively participate in and shape public systems as a community. It requires cooperation as well as transparency and institutional trust. This not only creates vibrant places to live and work in, but also builds a resilient civic ecosystem.

4. The Smartivist in practice: Global case studies

The following 10 case studies were selected through purposive sampling based on criteria such as geographic diversity, municipal leadership, degree of citizen engagement, and the availability of official strategy documents and civic tech platforms. They represent a spectrum of Smartivist approaches and were analyzed through document review and cross-case comparison to identify common patterns of digital participation, inclusive governance, and institutional innovation.

The rise of the Smartivist marks a decisive and conceptually grounded shift in urban development: from attracting creative talent to empowering civic innovation. While Richard Florida's Creative Class theory offered a powerful lens for understanding urban transformation in post-industrial economies [1, 20], it largely focused on attracting and retaining highly skilled individuals through quality of place, tolerance, and cultural vibrancy. These creatives were seen as drivers of innovation and competitiveness while still functioning primarily as consumers of place.

As the Smart City movement gained momentum in the 2010s, it became clear that technological infrastructure alone could not solve the complex social and environmental challenges cities face. What was missing was the activation of citizens not just as residents but as co-creators. Enter the Smartivist: a functionally defined, purpose-driven individual who leverages digital tools, creative capacity, and civic motivation to improve public life.

Unlike the Creative Class, which was characterized by occupational categories—artists, engineers, scientists [1, 4]—the Smartivist is defined by action. A Smartivist can be a student, a coder, a retiree, or a teacher; what matters is not their title but their contribution to shaping inclusive, participatory urban futures. As urban theorist Anthony Townsend observed, “the city itself is becoming a platform for innovation” [13] and Smartivists are those who interact with that platform as users, builders, and stewards.

This shift implies a redefinition of the city's role: from attracting human capital to cultivating civic agency. Cities that once competed for talent must now empower it by designing infrastructures of participation, ensuring open access to data, and enabling co-decision-making. Urban value creation is being reoriented: away from symbolic amenities and toward systems that support collaboration, transparency, and shared responsibility.

The 10 initiatives presented below span diverse political, cultural, and economic environments. What unites them is a shared commitment to enabling the Smartivist: to creating conditions under which citizens can step into roles as co-designers, problem-solvers, and public innovators. These cases reflect a growing recognition that human creativity, when activated at scale and connected through digital infrastructures, becomes a transformative civic force.

Each example should thus be read not only as a best practice in smart governance but also a concrete expression of a broader shift: from the creative worker to the engaged digital citizen. From Krefeld to Maputo, from Boston to Helsinki, Smartivists are emerging as the protagonists of a new urban logic—one grounded in participation, purpose, and collective intelligence.

While the contexts vary, all 10 cases exhibit core attributes of Smartivist engagement: digital fluency (e.g., Seoul, Helsinki), civic participation (e.g., Boston, Siegburg), a collaborative mindset (e.g., Mexico City, Tel Aviv), place-based loyalty (e.g., Freiburg, Krefeld), and systems thinking (e.g., Maputo, Helsinki). Together, they show that the success of tomorrow's cities depends not only on infrastructure or innovation. It also depends on the ability to identify, support, and activate Smartivists.

4.1 Smart Krefeld (Germany)

The German city of Krefeld provides a compelling example of the Smartivist in action. Under the Smart Krefeld initiative, municipal officials launched participatory formats to collaboratively shape the city's digital strategy. Events, such as the "Tag der Smart City," structured workshops and integration with the Beteiligung. NRW platform enabled residents to propose, debate, and prioritize local innovations [21]. Over 140 ideas were submitted during two online participation phases, and more than 600 stakeholder interactions were recorded throughout the strategy development process. Krefeld also introduced a 3D city model and a digital city map to enhance transparency in urban planning. The resulting strategic framework, adopted in 2022, embedded civic input across multiple domains and translated citizen vision into actionable projects.

This case marks a shift from the aesthetics of creative placemaking, as theorized by Creative Class theory [1], toward infrastructures of civic participation. Krefeld's approach empowered citizens as co-creators of urban futures and not only as cultural consumers. The Smartivist emerges here as a digitally fluent citizen who helps code the city's trajectory through dialog, design, and democratic engagement. As one city moderator emphasized: "From vision to action – Krefeld turned ideas into real solutions."

4.2 Smart City Siegburg (Germany)

Siegburg's approach, titled "Zukunft gemeinsam gestalten" ("Shaping the future together"), exemplifies co-design over mere consultation. Using the

open-source CONSUL-based platform mitmachen.siegburg.de, over 1000 citizens engaged in surveys, idea contests, and in-person workshops [22, 23]. The platform allows for continuous idea submission and feedback, while targeted events like Digital Day—held at schools and public spaces—served as hubs for civic engagement. More than 50 participants joined cross-sectoral workshops, leading to the development of 29 Smart City projects shaped by citizen input. Evaluation results showed that 80% of participants felt more engaged in local affairs after contributing to the process.

While Florida's Creative Class theory celebrated individual expression and cultural vibrancy, Siegburg institutionalizes digital participation as a civic infrastructure. The Smartivist in Siegburg contributes to collective intelligence, not through occupational identity, but through civic engagement and co-creation. "Siegburg didn't just listen – it gave citizens a seat at the table" became a local motto of participatory governance.

4.3 Mayor's Office of New Urban Mechanics (Boston, USA)

Boston's MONUM is a pioneering civic innovation lab that treats public engagement not as a one-off event but as a continuous process. Since its founding in 2010, MONUM has launched over 100 civic prototypes, developed, and tested in collaboration with communities, researchers, and technologists [24].

This model represents a clear departure from Creative Class clustering. In Boston, Smartivists co-produce public services within a system supported by open data access, real-time feedback loops, and testing infrastructure. Pilot programs such as Street Bump and City Hall To Go demonstrate how experimental methods were institutionalized. MONUM demonstrates how everyday creativity can become institutionalized within democratic innovation processes.

4.4 Laboratorio para la Ciudad (Mexico City, Mexico)

Between 2013 and 2018, Mexico City's Laboratorio para la Ciudad operated as a civic innovation lab that rechanneled artistic creativity into institutional reform. Through 30+ hackathons, participatory policy design, and a digital platform for drafting the city's constitution, residents were empowered to shape urban governance [25].

Rather than promoting symbolic consumption, the Lab redefined imagination as a tool for democratic infrastructure. Smartivists in Mexico City co-authored policy—not as elected officials, but as imaginative civic collaborators. The Lab's work contributed to the inclusion of over 300 citizen proposals into the constitutional drafting process.

4.5 mVoting (Seoul, South Korea)

In Seoul, the mobile platform mVoting is part of the broader Democracy Seoul initiative. It enabled citizens to propose issues, vote in real time, and receive follow-up reports from government officials. By 2020, over 1.1 million votes had been cast, with more than 180 citizen proposals adopted into policy [26, 27].

This digital infrastructure scales participation beyond elite clusters. Smartivists in Seoul are equipped with mobile tools that transform governance into an active dialog. "In Seoul, every citizen is a potential mayor" encapsulates this redefinition of civic agency.

4.6 MOPA—Monitoria Participativa de Maputo (Mozambique)

The MOPA platform facilitates citizen reporting of sanitation issues *via* SMS or USSD, bypassing the need for smartphones or Internet access. Between 2016 and 2020, over 70,000 reports were submitted by residents, helping municipal waste services target interventions more efficiently [28, 29].

In contrast to high-tech Smart City models, MOPA illustrates that the Smartivist can emerge in low-resource contexts. Here, the Smartivist is not an elite creative but a grassroots problem-solver, as he is co-producing public health through accessible digital tools. Civic resilience, in this setting, is driven by distributed, everyday acts of creativity.

4.7 Starachowice (Poland)

Starachowice, once an industrial powerhouse, lost its socio-economic role after the 1980s, creating a need for urban revitalization. Youth involvement became crucial for the Starachowice due to growing depopulation. The city launched the “Green School Participation Cottage,” allowing young people to submit school space management projects. In 2024, 52 projects were submitted, with 1893 people voting.

Using indicators such as poverty, poor infrastructure, and limited services, the city identified areas in need of support and created a 10-year Urban Revitalization Program. Residents can submit spatial and social project proposals, which are approved by the City Council. Implementation tools include online consultations and charrette workshops, where community ideas are quickly sketched and later turned into technical documentation.

Many European cities that were once economic powerhouses are facing the same problem of young people leaving and general depopulation. Starachowice shows that activating the young Smartivists still living there not only creates a stronger bond between the Smartivists and their city, but also addresses citizens’ problems in real time through charrette processes.

4.8 Smart Tel Aviv (Israel)

Tel Aviv’s strategy blends tech entrepreneurship with civic empowerment. The DigiTel personalized platform has over 300,000 registered users, and the open data portal enables residents to receive real-time updates and build new services [30].

This approach reframes the Creative Class’s entrepreneurial ethos as civic code literacy. Smartivists in Tel Aviv are not startup founders but agile civic developers, transforming data into public value. The city reports hundreds of co-created digital services each year. It is a testament to the fact that “citizen-centricity isn’t a feature – it’s the whole design.”

4.9 Smart Songdo (South Korea)

Initially conceived as a technocratic model, Songdo is shifting toward participatory frameworks. Starting in 2021, digital discussion boards, neighborhood panels, and co-design workshops have gradually been incorporating resident voices and increasingly integrating citizen input into urban planning processes [31].

This evolution shows that even in top-down environments, the Smartivist can emerge when digital systems are complemented by participatory infrastructure.

Continent	Country	City	Population	Civic tech tools	Key features
Europe	Germany	Krefeld	236,997	Beteiligung.NRW platform, 3D city model	140 citizen ideas submitted, participatory strategy development
Europe	Germany	Siegburg	42,274	CONSUL-based platform	mitmachen.siegburg.de, 29 citizen-driven Smart City projects
North America	USA	Boston	675,647	MONUM civic innovation lab, open data access	100+ civic prototypes, continuous co-creation process
North America	Mexico	Mexico City	22,752,400	Hackathons, digital platform for constitutional input	300+ citizen proposals integrated into the constitution
Asia	South Korea	Seoul	9,988,000	mVoting mobile platform	1.1 million votes, 180 proposals adopted into policy
Africa	Mozambique	Maputo	1,230,070	MOPA platform <i>via</i> SMS/USSD	70,000 sanitation reports <i>via</i> SMS/USSD, low-tech engagement
Europe	Poland	Starachowice	44,416	Online consultations, charrette workshops	Youth involvement in revitalization, online consultations and charrettes
Asia	Israel	Tel Aviv	495,600	DigiTel personalized platform, open data portal	300,000+ DigiTel users, co-creation of digital services
Asia	South Korea	Songdo	167,000	Digital discussion boards, co-design workshops	Shift from top-down planning to participatory processes
Europe	Finland	Helsinki	674,500	HRI open data portal, Helsinki Lab	1200+ open datasets, civic prototyping <i>via</i> Helsinki Lab

Table 1.
Smartivist case study overview.

In this context, the Smartivist challenges the automation narrative and advocates for inclusive, human-centered smart urbanism.

4.10 Smart Helsinki (Finland)

Helsinki demonstrates a systemic commitment to the Smartivist through its award-winning open data portal (HRI) and the Helsinki Lab, which fosters human-centered design and community prototypes [32].

Once a hub for Creative Class professionals, Helsinki now creates conditions in which the Smartivist can thrive as an empowered resident who engages with data, co-designs public services, and contributes to civic co-governance. Over 1200 open datasets and dozens of civic prototypes emerged from this ecosystem. The city's motto, "Openness is the operating system," reflects this shift: Every citizen is seen as a potential architect of collective urban futures.

Table 1 summarizes 10 international Smartivist case studies based on geographic diversity, availability of civic tech, and participatory infrastructure. Each city demonstrates unique strategies to empower digitally engaged citizens in shaping urban futures.

5. Activating the Smartivist: Managing change and building trust

Based on insights gained from two Smart City strategies supported by bee smart city, this section outlines concrete steps for activating the Smartivist in practice. These cases highlight that empowering Smartivists is not only a theoretical imperative, as it is a practical strategy for managing change and building public trust. As cities implement smart solutions, they must address a central challenge: How can urban leaders convince skeptical residents of the value of Smart City initiatives? The answer lies in activating Smartivists as trusted local changemakers who mediate between policy, technology, and the everyday needs of their communities.

Each of us is a citizen and therefore a potential Smartivist. Almost everyone owns a smartphone today, and many replace it every 2 to 3 years to stay up to date with the latest innovations. Likewise, most people regularly upgrade their cars, benefiting from ongoing advances in safety, connectivity, and energy efficiency. These habits reflect the rapid pace of innovation in the private sector, where consumers have come to expect continuous improvement.

Innovation cycles, however, differ dramatically across sectors. While the tech industry reinvents itself approximately every 2 years, the automotive sector operates on approx. 5-year development cycles. In stark contrast, public sector innovation often unfolds over 10 to 15 years. This temporal mismatch makes change in municipal governance particularly complex and slow-moving. Today, through faster, more expansive technology, all of these time horizons will accelerate—cities must catch up with the pace of change to truly serve their residents (**Figure 4**).

As a decision-maker in your city, accelerating these cycles requires your leadership. Adopt agile methods and streamlined decision-making, and explore how AI and automation can support efficiency and responsiveness. Look critically at existing regulatory and financial barriers. Whenever and wherever possible, reduce or redesign them. Most importantly, foster a culture of collaboration and open innovation that positions residents not as passive recipients but as active contributors to urban transformation.

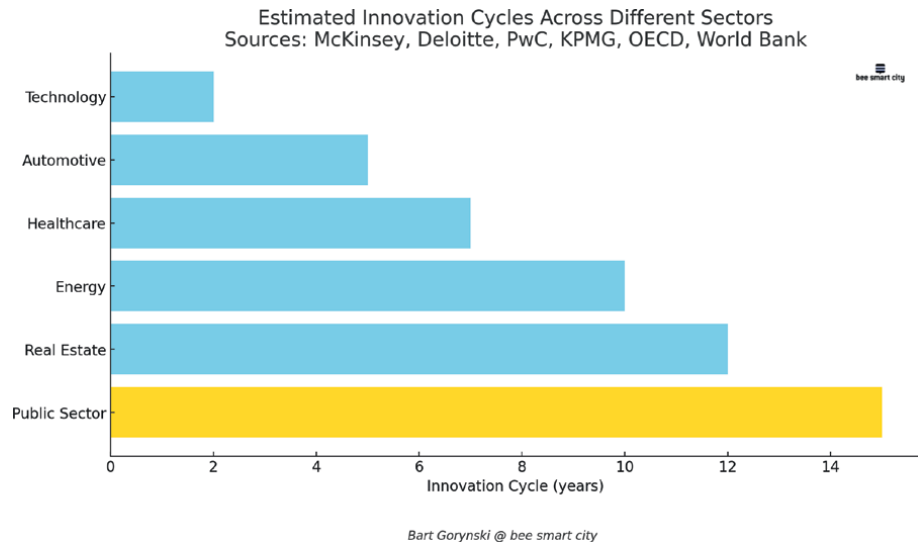


Figure 4.
Estimated innovation cycles across different sectors by McKinsey, Deloitte, PwC, KPMG, OECD, World Bank; specially designed illustrated by bee smart for this section city.

People do not fear innovation. They fear being left out of it. You and I, as residents, have shown we are willing to adopt innovation when it benefits us directly. What we resist is being excluded from shaping how that innovation unfolds.

5.1 Five actionable steps to activate the Smartivist in your city

Smartivists are essential to the creation of a Smart City. Here is a quick guide to finding, activating, and working with your local Smartivists.

5.1.1 Involve all residents early

Build trust from the beginning by engaging citizens: listening to their ideas, understanding their fears, and inspiring their actions—across all demographics—before decisions are made. Especially find ways to involve young people; give them a seat at the table as “discovery” Smartivist. In Krefeld, over 140 citizen-generated ideas and 600+ stakeholder interactions shaped the city’s digital strategy. In Siegburg, structured participation through mitmachen.siegburg.de and local workshops empowered residents to take part in co-creating future-oriented solutions. Lessons learned: When people co-create solutions, they own the change.

5.1.2 Identify and support local Smartivists

Seek out those in your community who are already engaged and curious. These Smartivists can become ambassadors for change, translating city visions into relatable language and helping others understand and support smart initiatives. Also, seek out those who are skeptical and resistant to your ideas; they will help you find new paths to change. In Krefeld and Siegburg, local changemakers played a pivotal role in building public momentum. Lessons learned: Smartivists are not just users, they are changemakers.

5.1.3 Enable iterative learning and feedback

Treat your city as a living lab. Pilot new ideas, test openly, and adjust based on real-time feedback from your residents. Reach out to enterprises, civic organizations and nonprofits as important influencers of pilots. Digital platforms and in-person dialog formats in both case studies created feedback loops that improved results and strengthened legitimacy. Lessons learned: People support what they help create.

5.1.4 Make benefits visible and tangible

Do not rely on abstract promises. Instead, show real improvements. Krefeld's 3D city model made urban planning tangible and transparent. In Siegburg, smart waste and water sensors delivered immediate, visible benefits in daily life. Lessons learned: Seeing is believing—showcase real benefits, not just ideas.

5.1.5 Link innovation to everyday value

Communicate how digital innovation contributes to better services, lower costs, and a greener city. Highlight shared values like sustainability to unify diverse groups around common goals. Both cities succeeded in anchoring innovation to practical improvements in service delivery and environmental quality. Lessons learned: A smarter city, the place we call home is not just efficient. It's livable.

5.2 Empowering Smartivists means empowering the city

Winning over skeptics is not a question of persuasion but of inclusion. As a leader, your role is to create the conditions in which citizens do not just participate: They co-decide, co-design, and co-create. People do not resist change—they resist feeling unheard. In the age of digital transformation, the Smartivist becomes the linchpin of successful urban innovation. Their activation is not a supplementary step. It rather is the strategy.

6. Conclusion

The evolution from the Creative Class to the Smartivist marks a paradigmatic transformation in how we understand urban innovation, citizenship, and agency.

This shift reflects a broader realignment: from cities designed to attract talent through symbolic capital to cities designed to empower digitally fluent, civically committed citizens as co-creators of public value.

While the Creative Class emphasized cultural clustering and lifestyle-driven growth, the Smartivist embodies civic capital, systems thinking, and collaborative problem-solving as the new engines of urban transformation. The city is no longer a stage for creative consumption. It becomes an infrastructure for participatory governance and distributed innovation.

This reconceptualization has far-reaching implications:

- For urban theory, it expands traditional models of human capital by integrating concepts like technological citizenship, digital participation, and civic tech [16, 17].

- For governance, it calls for enabling infrastructures like open data ecosystems, co-creation labs, and inclusive digital platforms that structurally embed citizen engagement.
- For policy, it requires a shift from symbolic consultation to institutional openness, from image-building to collective intelligence, and from individual talent to networked civic capacity.

Engagement is not just about asking for opinions; it is about empowering citizens to shape their cities. Therefore, citizen engagement is a continuous conversation, not only a one-time survey. The case studies presented—from Krefeld to Maputo, Boston to Helsinki—demonstrate that the Smartivist is not a theoretical construct but an observable agent of change. These actors operate across roles: as voters, developers, critics, stewards, and co-implementers of urban innovation. What defines them is not profession; instead, it is their purpose—a commitment to shaping inclusive and resilient urban futures through digital and civic agency.

Crucially, the Smartivist does not replace the Creative Class but transcends it. They retain the Creative Class's drive for innovation and autonomy, yet redirect it toward the common good. Their creativity is not limited to cultural output or economic productivity, as it is applied to reimagining governance systems, mobilizing communities, and designing democratic infrastructures. Innovation thrives when citizens lead through technology. Sustained engagement requires digital inclusion—not just access, but agency.

In this light, the Smartivist becomes both agent and interface—a human node where technology, governance, and collective intelligence converge. As Anthony Townsend observed “the city itself is becoming a platform for innovation,” and Smartivists are those who interact with this platform as users, coders, co-creators, and catalysts of change.

As cities worldwide confront the intertwined challenges of digitalization, inequality, and ecological crisis, the Smartivist offers a compelling blueprint for the future. Their presence calls for a civic infrastructure that recognizes, supports, and scales their contributions. The future of smart urbanism does not lie in technology alone. It lies in activating Smartivists who embody participatory values and democratic resilience.

The Smartivist is already here. The challenge ahead is not to imagine them—but to empower them.

A. Comparative definitions—From Creative Class to Smartivist

Commentary by Sandra Baer, CEO of Personal Cities and Brand Ambassador at SmartCitiesWorld, Washington, D.C., USA, sandra@personalcities.org

As the conversation around urban innovation matures, one essential element rises to the surface: Trust. Without trust, no technology can transform a city, no data can build community, and no innovation can take root. From Richard Florida's vision of the Creative Class to the emergence of the Smartivist, we observe a paradigmatic shift—not just in how cities function, but in how they build relationships.

“The Creative Class is made up of people whose economic function is to create new ideas, new technology, and new creative content.” ([33], p. 8)

Richard Florida's Creative Class captured a generation driven by cognitive labor and creative output. This class helped cities thrive by contributing to economic growth through innovation, artistry, and design. Yet, its model was primarily one of attraction: attracting talent, investment, and vibrancy through cultural capital.

“The Smartivist, a smart sustainable city activist, is the civic evolution of the Creative Class: a digitally fluent, socially conscious urban innovator who not only produces creative and economic value but also contributes actively to shaping inclusive, participatory, and resilient cities” [34].

The Smartivist takes this narrative further. In the context of digital transformation, the Smartivist is not only a creative force—they are a catalyst for trust. They co-create, collaborate, and connect across digital and physical spaces. They build confidence in governance through transparency, accountability, and inclusion.

This shift from Creative Class to Smartivist is rooted in three transformational forces:

- The expansion of public services into digital realms, requiring new forms of digital literacy and public engagement;
- The evolution of Smart Cities into multi-layered ecosystems, where residents are co-creators, not passive recipients;
- And, most importantly, the realization that trust is the foundation of innovation.

Cities that empower Smartivists are cities that trust their people—and that invite people to trust back. This reciprocal trust is the true smart infrastructure of the twenty-first century.

As someone who works closely with civic leaders and communities around the globe, I see this shift every day. Cities thrive when they put people at the center—not only as users of smart technologies but also as shapers of shared futures.

The Smartivist is a response to complexity but also a source of hope. They remind us that Smart Cities are not made by infrastructure alone, but by the relationships we nurture, the voices we uplift, and the spaces we open for collective imagination.

Author details

Bart Gorynski
bee smart city GmbH, Muelheim an der Ruhr, Germany

*Address all correspondence to: bart@beesmart.city

IntechOpen

© 2025 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. 

References

- [1] Florida R. *The Rise of the Creative Class: And How It's Transforming Work, Leisure, Community and Everyday Life*. New York: Basic Books; 2002
- [2] Becker GS. *Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education*. New York: Columbia University Press; 1964
- [3] Lucas RE. On the mechanics of economic development. *Journal of Monetary Economics*. 1988;**22**(1):3-42
- [4] Pratt AC. Creative cities: The cultural industries and the creative class. *Geografiska Annaler: Series B, Human Geography*. 2008;**90**(2):107-117
- [5] Peck J. Struggling with the creative class. *International Journal of Urban and Regional Research*. 2005;**29**(4):740-770
- [6] Florida R. *The New Urban Crisis: How Our Cities Are Increasing Inequality, Deepening Segregation, and Failing the Middle Class—And What We Can Do About It*. New York: Basic Books; 2017
- [7] Cunningham S, Potts J. Creative industries and the wider economy. In: Jones C, Lorenzen M, Sapsed J, editors. *The Oxford Handbook of Creative Industries*. Oxford: Oxford University Press; 2015. pp. 387-404
- [8] Evans J, Karvonen A. Living laboratories for sustainability: Exploring the politics and epistemology of urban transition. *Cities*. 2011;**29**(1):1-10
- [9] bee smart city GmbH: *Smart City Smart Region: Handlungsleitfaden für Praktiker*innen*, 2019 (Further Developed Multi-Layered Structure of Smart Cities and Regions in 2024)
- [10] Komninos N. *Intelligent Cities: Innovation, Knowledge Systems and Digital Spaces*. London: Routledge; 2002
- [11] Giffinger R, Fertner C, Kramar H, Kalasek R, Pichler-Milanović N, Meijers E. *Smart Cities—Ranking of European Medium-Sized Cities*. Vienna: Centre of Regional Science, Vienna UT; 2007
- [12] Anthopoulos LG. *Understanding Smart Cities: A Tool for Smart Government or an Industrial Trick?*. Cham, Switzerland: Springer; 2017
- [13] Townsend AM. *Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia*. New York: W. W. Norton & Company; 2013
- [14] Cardullo P, Kitchin R. Being a 'citizen' in the Smart City: Up and down the scaffold of smart citizen participation in Dublin, Ireland. *GeoJournal*. 2019;**84**(1):1-13
- [15] bee smart city GmbH. *Towards a New Smart City Definition* [Internet]. 2021. Available from: <https://www.beesmart.city/en/strategy/smart-city-definition> [Accessed: March 23, 2025]
- [16] Feenstra R, Keane J. Democratising the digital: The role of technological citizens in the Smart City. In: Isin EF, Ruppert E, editors. *Being Digital Citizens*. London: Rowman & Littlefield; 2014. pp. 226-245
- [17] Mossberger K, Tolbert CJ, McNeal RS. *Digital Citizenship: The Internet, Society, and Participation*. Cambridge, MA: MIT Press; 2008
- [18] bee smart city GmbH. *Smartivist Accelerate Smart City Development*

- [Internet]. 2023. Available from: <https://www.beesmart.city/en/solutions/smartivist> [Accessed: March 23, 2025]
- [19] Schrock A. Civic Tech: Making Technology Work for People. London: Rowman & Littlefield; 2018
- [20] Florida R. Cities and the Creative Class. New York: Routledge; 2005. 198 p
- [21] Stadt Krefeld. Digitale Stadtstrategie Krefeld. Krefeld: Stadtverwaltung Krefeld; 2022. 96 p
- [22] Stadt Siegburg. Smart City Strategie. Siegburg: Stadt Siegburg; 2023. 72 p
- [23] Mitmachen Siegburg. Online Citizen Participation Platform [Internet]. Available from: <https://mitmachen.siegburg.de/>
- [24] City of Boston. Mayor's Office of New Urban Mechanics [Internet]. Available from: <https://www.boston.gov/departments/new-urban-mechanics> [Accessed: March 22, 2025]
- [25] Laboratorio para la Ciudad. Mexico City Urban Innovation Lab (Archived) [Internet]. Available from: <https://www.labcd.mx> [Accessed: March 22, 2025]
- [26] Seoul Metropolitan Government. Democracy Seoul [Internet]. Available from: <https://democracy.seoul.go.kr> [Accessed: March 22, 2025]
- [27] Lee J. Civic engagement through mobile participation: The case of mVoting in Seoul. In: Digital Democracy in Asia. Seoul: Korea Democracy Foundation; 2018. pp. 55-72
- [28] World Bank. Maputo Urban Transformation Program: Community Engagement through Digital Platforms. Washington, DC: The World Bank Group; 2020. 56 p
- [29] Smart Africa Alliance. Civic Tech in Africa: Use Cases and Insights. Kigali: Smart Africa Secretariat; 2021. 40 p
- [30] Municipality of Tel Aviv. Smart City Strategy and Digital Platform [Internet]. Available from: <https://www.tel-aviv.gov.il> [Accessed: March 22, 2025]
- [31] Incheon Free Economic Zone Authority. Songdo Smart City Master Plan. Incheon: IFEZA; 2021. 104 p
- [32] Helsinki Region Infoshare. Open Data and Helsinki Lab Initiatives [Internet]. Available from: <https://hri.fi> [Accessed: March 22, 2025]
- [33] Florida R. The Rise of the Creative Class: And How It's Transforming Work, Leisure, Community and Everyday Life. Basic Books. 2002
- [34] Gorynski B. The Rise of the Smartivist: From Creative Class to Citizen-Centric Smart Sustainable Cities. Chapter Above. 2025

Smart Cities and Surveillance Technology: Balancing Innovation, Security, and Privacy in Urban Environments

Ahmed Hassebo

Abstract

The integration of surveillance technology into smart cities is transforming urban living, enhancing security, traffic management, and emergency response systems. This research examines the role of artificial intelligence, facial recognition, IoT-connected sensors, and predictive analytics in modern surveillance infrastructures. While these technologies improve efficiency and public safety, they also raise ethical concerns regarding privacy, data security, and government oversight. The study explores how urban planners, policymakers, and technologists can design surveillance frameworks that align with democratic values, ensuring transparency and accountability. Additionally, the research investigates citizen perceptions, legal implications, and potential solutions to mitigate privacy risks while optimizing security measures. By analyzing global case studies, the study aims to provide insights into designing responsible surveillance systems that support smart city initiatives while preserving individual freedoms.

Keywords: smart cities, IoT, surveillance technology, AI, 5G, public safety

1. Introduction

According to the United Nations (UN), the global population reached 8.0 billion in 2022, representing more than a threefold increase since 1950. Projections indicate that the population will rise to 8.5 billion by 2030, 9.7 billion by 2050, and 10.7 billion by 2100 [1]. In 1950, around 70% of the global population lived in rural areas. A significant shift occurred in 2007 when, for the first time, the urban population surpassed the rural population. By 2018, 55% of the world's population—approximately 4.2 billion people—resided in urban areas. This proportion is expected to rise to 60% by 2030 and further to 68% by 2050, effectively reversing the rural-urban distribution observed in the mid-twentieth century [2].

Due to the projected increased demand for urbanization [2], the demand for smart cities and their associated applications and services is anticipated to grow

significantly. Allied Market Research reports that the global smart cities market was valued at \$648.4 billion and is projected to reach \$6.0 trillion by 2030, reflecting a compound annual growth rate (CAGR) of 25.2% between 2021 and 2030 [3]. Consequently, the number of smart cities aimed at improving residents' quality of life (QoL) is expected to rise. According to the Smart City Observatory of the IMD World Competitiveness Center (WCC), the number of smart cities grew from 118 in 2021 to 141 in 2023 [4]. According to Statista, the global smart city market is projected to reach approximately \$72.5 billion in 2024. This upward trend is expected to continue with a compound annual growth rate (CAGR) of 9.7% from 2024 to 2029, resulting in an estimated market volume of \$113.5 billion by 2029 [5].

The United States is expected to continue its urbanization trend in the coming decades, with the proportion of the population living in urban areas steadily increasing. As of 2023, approximately 80% of Americans reside in urban areas, while 20% live in rural regions—a slight shift from 2010 figures of 80.7% urban and 19.3% rural. According to the United Nations Department of Economic and Social Affairs (UN DESA), the U.S. urban population is projected to grow by 15.2 million between 2020 and 2030, reaching 268.4 million, while the rural population is expected to remain relatively stable at around 60 million. By 2050, urban residents are projected to comprise 89% of the total population, with rural residents representing just 11%. This urbanization is primarily driven by factors such as employment opportunities, access to education, modern infrastructure, and transportation services [6]. On the other hand, urbanization presents several challenges, including housing affordability, social inequality, and traffic congestion. To address these issues, governments must implement strategic interventions—such as investing in infrastructure and essential services like affordable housing, efficient public transportation, and accessible education. Additionally, targeted policies are required to mitigate urban inequality by tackling poverty, crime, and social exclusion, thereby promoting inclusive and sustainable urban development.

Emerging Internet of Things (IoT) applications—such as smart health, smart grids, smart water management, smart cities, and intelligent transportation systems (ITS)—are poised to revolutionize modern life and work. IoT technology is already powering billions of interconnected smart devices and sensors that communicate and operate remotely via the Internet. As of now, there are over 15 billion IoT-connected devices globally. This number is projected to exceed 29 billion by 2030, representing a threefold increase compared to 2020 [7]. According to the International Data Corporation (IDC), global IoT spending is projected to grow significantly, rising from \$726 billion in 2019 to \$1.1 trillion by 2023. Additionally, IoT Analytics' Global IoT Enterprise Spending Dashboard estimates that the enterprise IoT market will expand at a compound annual growth rate (CAGR) of 19.4%, reaching \$483 billion between 2022 and 2027 [8].

The IoT is denoted as machine-to-machine (M2M) communication, therefore, a staggering number of “things” will require ubiquitous connectivity [9]. These connected devices encompass a wide range of applications, including household appliances, smart home systems, industrial machinery, vehicles, and even entire urban infrastructures [10]. IoT devices are generally outfitted with sensors that gather environmental data—such as temperature, humidity, and motion, as well as operational data like power consumption and performance metrics [11]. This data is transmitted via the internet to other devices or systems, where it can be analyzed to support decision-making and trigger appropriate actions.

There is growing agreement that cellular technologies—both legacy Fourth Generation 4G Long Term Evolution (LTE) and emerging Fifth Generation 5G are the primary candidates to provide the global connectivity needed for the massive scale of IoT devices. Unlike previous generations, 5G will not simply combine old and new radio access technologies (RAT); it will enable entirely new use cases and mobile communication demands beyond those supported by 4G. This evolution will integrate existing 4G standards with disruptive technologies like millimeter wave (mmWave) and spectrum sharing, driven by emerging services and increased demand [12]. By 2030, billions of interconnected devices are expected to operate at data rates of several gigabits per second, enabling personalized user experiences with ultra-low latency and high reliability [9].

2. Smart cities

A smart city is an urban environment that leverages digital technologies, data analytics, and Internet of Things (IoT) sensors to improve residents' quality of life, optimize infrastructure efficiency, stimulate economic growth, and advance sustainable development. As illustrated in **Figure 1**, the smart city concept covers multiple dimensions such as governance, mobility, environment, sustainability, data management, and overall quality of life [13].

Smart cities depend on a strong infrastructure and connectivity backbone, where digital technologies like IoT devices, high-speed internet, and interoperable systems facilitate seamless data exchange. These components enable efficient urban services, sustainability initiatives, and innovation. At the core, IoT sensors monitor key sectors such as traffic, public safety, waste management, water, and energy, empowering cities to make informed, real-time decisions that enhance quality of life. By leveraging data analytics and AI, smart cities obtain predictive insights and automate processes across urban planning, public safety, and infrastructure management, boosting operational efficiency and responsiveness [13, 14].

Sustainable development in smart cities integrates economic, social, and environmental goals, using green infrastructure, resource-efficient practices, and inclusive

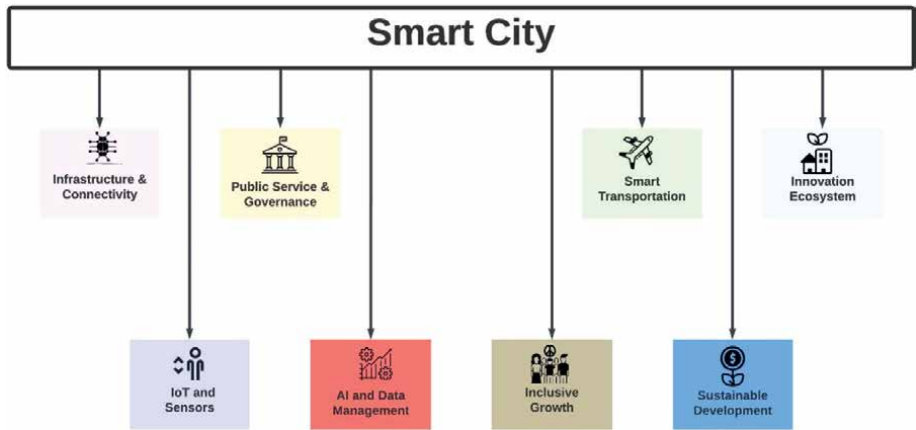


Figure 1.
Smart city aspects.

governance to ensure long-term livability. Transportation is a key sector, with smart mobility solutions—including ITS, EVs, real-time analytics, and autonomous vehicles—aiming to reduce congestion, enhance safety, and lower environmental impact. Finally, smart governance emphasizes digital public services, citizen engagement, and transparent decision-making, ensuring cities are responsive, equitable, and adaptable to change. Together, these interconnected components form the core of a smart city ecosystem designed for resilience, efficiency, and inclusivity [14].

There are many smart cities around the world that are implementing advanced technologies to improve the Quality of lives of their citizens, increase sustainability, and enhance the efficiency of city. As illustrated in **Figure 2**, to develop smart cities, there are three open-ended phases defined as Smart City 1.0, 2.0, 3.0, and 4.0 [15] inspired by economics.

- *Smart City 1.0* represents the foundational stage of smart urban development, focusing on pilot projects, demonstrations, and proof-of-concept efforts to evaluate innovative technologies in real-world contexts. Targeting areas such as transportation, energy, waste management, safety, and healthcare, cities begin integrating digital technologies, IoT devices, sensors, and data analytics into existing infrastructure to enhance efficiency, sustainability, and resilience. This phase emphasizes data collection from diverse sources, including citizens to inform decision-making and improve services, while fostering collaboration among governments, private sectors, academia, and communities to establish governance structures and shared platforms. Key activities include upgrading urban infrastructure to enable automation and connectivity, crafting regulatory frameworks to ensure privacy and security, and promoting digital awareness and skill-building through education and training. Although this stage lays the groundwork for innovation and growth, it also introduces challenges related to scalability, integration, governance, funding, and privacy, all of which require strategic planning, coordination, and effective management [16, 17].
- *Smart City 2.0* builds on the foundations of Smart City 1.0 by focusing on seamless integration across systems, technologies, and sectors to create a unified,

Smart City 1.0	Smart City 2.0	Smart City 3.0	Smart City 4.0
Technology providers often offer pilot solutions, but they frequently view technology as the ultimate goal rather than a tool to address citizens' needs. As a result, Smart Cities 1.0 typically lack the capacity to fully leverage these investments and often misunderstand their real impact on the public.	They prioritize digital solutions to advance their social goals, recognizing that technology can enhance many public services. However, they often fall short of gaining widespread citizen support, as many residents are excluded from the decision making process.	They are aware of sensitive social and digital challenges, actively involve citizens in decision-making, and work to represent their interests. Additionally, they recognize the transformative power of technology to connect and enhance the urban ecosystem.	Are hyberconnected cities that use technology, data, and citizen engagement to achieve the SDGs. They are in step with new ways of working under industry 4.0 and excel at using partners to drive change and provide innovative funding methods.

Figure 2.
Smart city development phases.

scalable, and sustainable urban environment. It leverages data analytics, AI, and machine learning for smarter decision-making while ensuring responsible data governance and privacy. Citizen engagement is central, with digital tools enabling participation and feedback. Sustainability and inclusivity are prioritized through green practices, climate resilience, and policies that bridge digital and social divides. Cities also foster innovation via supportive ecosystems for startups and partnerships, all under unified regulatory frameworks aligned with broader goals, though the phase introduces greater complexity [16, 18].

- *Smart City 3.0* envisions a hyperconnected, intelligent urban ecosystem driven by advanced technologies such as 5G/6G [19, 20], quantum and edge computing, blockchain, IoT, AI, robotics, and immersive technologies like AR/VR. It focuses on real-time data sharing, personalized services, autonomous systems, and context-aware solutions to enhance governance, efficiency, and quality of life. Emphasizing sustainability, it promotes circular economies, green innovations, and adaptive infrastructure to address climate and societal challenges. Citizen-centricity, inclusivity, and ethical technology use are core, ensuring equitable access, participation, and transparent governance. This speculative model aims to create resilient, innovative, and sustainable cities for the future [16, 19].
- *Smart City 4.0* predicts a fully integrated, adaptive urban ecosystem where technologies, systems, sectors, and stakeholders converge through digital twins, cyber-physical systems, and ecosystem thinking to enable seamless coordination and synergy. It emphasizes decentralized, resilient infrastructure powered by blockchain, DeFi, edge computing, swarm intelligence, and peer-to-peer networks to ensure secure, efficient, and self-sustaining delivery of urban services and resources. Advanced technologies such as cognitive computing, autonomous systems, artificial general intelligence (AGI), and swarm robotics drive self-learning and self-optimizing urban processes capable of real-time adaptation. Central to this vision is symbiotic human-machine collaboration, leveraging brain-computer interfaces, exoskeletons, human-computer interaction, and augmented intelligence to enhance human creativity, productivity, and well-being within the urban environment [20, 21]. Furthermore, Smart City 4.0 envisions a regenerative, resilient urban ecosystem inspired by nature, with decentralized, self-optimizing infrastructure powered by technologies like blockchain and cognitive computing. It promotes human-machine collaboration through advanced interfaces and prioritizes ethical, inclusive innovation focused on privacy, social responsibility, and community engagement. Supported by global partnerships, this visionary model aims to build smarter, sustainable, and equitable cities for future generations [20].

The essence of a smart city lies not only in the adoption of advanced technologies but also in the integration of systems that promote sustainability, transparency, and citizen engagement. Through strategic planning and intelligent infrastructure, smart cities aim to optimize resource consumption, improve service delivery, and foster inclusive economic growth. Importantly, the success of a smart city depends not just on technological prowess but also on a participatory approach that includes urban residents in decision-making processes. Artificial Intelligence (AI) and big data analytics are also critical, allowing cities to analyze large volumes of data to identify trends, make predictions, and optimize services. For example, AI-powered traffic

systems can reduce congestion by dynamically adjusting signals based on vehicle flow. Meanwhile, cloud computing and 5G networks facilitate high speed, secure communication between devices and systems, ensuring the seamless exchange of information across city departments.

The benefits of smart cities are manifold. First and foremost, they offer a path to environmental sustainability. By leveraging smart grids, renewable energy, and efficient transportation, cities can reduce greenhouse gas emissions and conserve natural resources. Waste reduction and water conservation technologies further contribute to a more sustainable future. Smart cities also promise an improved quality of life for residents. Enhanced public services, reduced commuting times, and better access to healthcare and education lead to more livable urban environments. For instance, smart lighting systems not only save energy but also enhance public safety by adjusting brightness based on pedestrian activity. Public safety is another area where smart cities excel. Surveillance systems, emergency response coordination, and predictive policing technologies enable faster, more effective interventions during emergencies. Meanwhile, data-driven urban planning ensures that cities grow in a manner that is both inclusive and adaptive to future needs.

Despite their advantages, smart cities face several challenges and risks. A primary concern is data privacy and cybersecurity. The extensive data collection required to operate smart systems raises questions about who controls the data, how it is used, and how it is protected from breaches. The cost of implementation is another barrier. Building the digital infrastructure necessary for a smart city requires significant investment, which may not be feasible for all municipalities, especially in developing regions. Furthermore, there is a risk of creating technological inequality, where only affluent neighborhoods or citizens benefit from smart technologies. Technological dependency also presents a vulnerability. Over-reliance on automated systems can make cities susceptible to failures or cyberattacks. Additionally, governance issues such as unclear regulations, lack of coordination among agencies, and insufficient public involvement can hinder the success of smart city initiatives. Smart cities represent a forward-thinking response to the complexities of urbanization in the digital age. By integrating technology, data, and inclusive governance, they offer innovative solutions to traditional urban problems, making cities more livable, efficient, and sustainable. However, realizing the full potential of smart cities requires careful attention to ethical considerations, equitable access, and robust infrastructure. As we look to the future, the role of citizens, policymakers, and technologists will be pivotal in shaping the direction of smart city development. The challenge lies in striking a balance between innovation and inclusivity, ensuring that smart cities are not just technologically advanced, but also socially just and environmentally responsible.

3. Surveillance technology in smart cities

Surveillance technology has become a cornerstone of modern smart cities, playing a pivotal role in ensuring safety, managing public spaces, and enhancing the delivery of city services. In a smart city, surveillance extends beyond traditional cameras and law enforcement tools. It is embedded in a complex network of sensors, artificial intelligence (AI), facial recognition, and real-time data analysis. These technologies work together to create a constantly monitored urban environment, designed to be responsive, predictive, and efficient. However, the increasing presence of surveillance also raises profound concerns about privacy, consent, and civil liberties.

While surveillance can empower cities to function more effectively, it can also lead to overreach, particularly when deployed without transparent governance or citizen oversight. Understanding both the technological benefits and the socio-political implications of surveillance in smart cities is essential for creating ethical and inclusive urban futures [13, 21].

Smart cities deploy a wide array of surveillance technologies to monitor and manage public life. These include closed-circuit television (CCTV) cameras with AI-based facial and object recognition, license plate readers, environmental sensors, and drones. Integrated with big data analytics, these systems provide authorities with real-time insights into traffic patterns, criminal activity, crowd density, and even social behavior. One major application is in predictive policing; by analyzing historical crime data and correlating it with current surveillance inputs, AI algorithms can forecast potential hotspots for crime, allowing law enforcement to act preemptively. Similarly, smart surveillance is used in public safety monitoring, especially during large events, protests, or emergencies, where it helps to direct crowd movement and emergency response teams effectively [13].

One of the most prominent applications of smart surveillance is in public safety and crime prevention. AI-powered cameras can recognize faces, detect abnormal behaviors, and alert authorities to potential threats before incidents escalate. London, for example, has implemented facial recognition systems to monitor high-risk public areas, aiding police in identifying suspects and missing individuals. Similarly, in Singapore, smart surveillance plays a key role in maintaining public order by analyzing real-time footage and identifying security risks swiftly. In the realm of traffic and transportation management, smart cameras help monitor vehicle movement, detect traffic violations, and manage congestion. These systems are often integrated with traffic signals to optimize traffic flow dynamically. Singapore's Intelligent Transport System utilizes such technologies to minimize traffic jams and enhance road safety, with surveillance data being central to this adaptive infrastructure. Environmental monitoring also benefits from smart surveillance integration.

Cameras equipped with pollution sensors can identify illegal dumping activities or monitor industrial emissions. Shenzhen, China, has adopted such systems extensively in its industrial districts to ensure regulatory compliance and environmental sustainability. Smart surveillance is also instrumental in urban planning and infrastructure maintenance. Data collected from surveillance cameras can reveal pedestrian movement patterns, allowing planners to redesign urban spaces for greater accessibility and safety. In Barcelona, video analytics are used to inform urban mobility strategies and improve pedestrian infrastructure. These systems can also automatically detect infrastructure issues, such as potholes or damaged street furniture, triggering timely maintenance. Emergency response and disaster management are further enhanced by real-time surveillance systems. During crises such as natural disasters, fires, or terrorist attacks, smart cameras provide live visual feeds to emergency responders, enabling faster and more coordinated interventions. New York City exemplifies this through its Domain Awareness System, which integrates over 9000 surveillance cameras with other sensor data to support public safety and emergency preparedness efforts [13, 22].

Despite these advantages, the proliferation of surveillance in smart cities has sparked significant ethical and legal debates. At the center of these concerns is the issue of privacy. Constant monitoring, especially when powered by AI and facial recognition, can create a sense of perpetual surveillance, altering the behavior of citizens and infringing on personal freedoms. The lack of transparency in how

surveillance data is collected, stored, and used adds to these concerns. In many cities, surveillance systems are deployed without clear consent from the public, and without independent oversight. Questions arise about who has access to the data, how long it is stored, and whether it can be used for purposes beyond the original intent—such as political repression or discriminatory profiling. Moreover, bias in surveillance algorithms presents another layer of risk. Facial recognition systems have been shown to identify individuals from minority groups at higher rates, potentially leading to wrongful detention or unjust targeting. In the absence of regulation, these systems can exacerbate existing inequalities rather than mitigate them [13].

4. Case studies

- Singapore stands as a leading example of a city extensively deploying smart surveillance. Under its Smart Nation initiative, the city-state has implemented the Smart Nation Sensor Platform, which includes smart lampposts outfitted with surveillance cameras, environmental sensors, and facial recognition capabilities. These systems are used to monitor crowd density, detect public disturbances, and collect environmental data, forming a comprehensive tool for urban governance.
- Barcelona, known for its innovative approach to urban development, uses smart surveillance not only for safety but also for managing tourism and urban mobility. Cameras across the city monitor traffic and crowd patterns, providing real-time data that informs public transportation adjustments and pedestrian area designs. This integration supports the city's commitment to sustainable and inclusive urban growth.
- Dubai has invested heavily in becoming a fully integrated smart city. Through its “Oyoon” (Arabic for “eyes”) program, the city has installed thousands of AI-enabled surveillance cameras in public areas. These are used for crime prediction, face and license plate recognition, and monitoring violations such as jaywalking or illegal parking. The collected data is shared across government departments to streamline citywide decision-making.
- In London, the deployment of smart surveillance is tied closely to law enforcement. The city uses live facial recognition to scan public areas for individuals of interest, though the initiative has sparked debates around privacy and civil liberties. Nonetheless, London's integration of surveillance with predictive policing tools demonstrates the increasing role of AI in urban security strategies.
- Shenzhen, often dubbed the Silicon Valley of China, is another pioneer in smart surveillance. With over one million cameras installed, the city uses them for everything from facial recognition at crosswalks to monitoring student behavior in classrooms. It also employs surveillance for environmental protection, ensuring industrial zones comply with emission regulations.
- Finally, New York City provides a compelling case with its Domain Awareness System (DAS), developed in partnership with Microsoft. This platform aggregates data from surveillance cameras, license plate readers, and other sensors

into a single interface accessible to police and emergency services. DAS enhances situational awareness and rapid response capabilities, particularly in densely populated and high-risk areas.

5. Artificial intelligence (AI) and IoT

AI refers to the simulation of human intelligence in machines that are programmed to think and learn like humans. It involves developing computer systems and algorithms that can perform tasks that typically require human intelligence, such as speech recognition, problem solving, decision making, and visual perception. AI technologies are being applied across numerous industries and sectors, including healthcare, finance, transportation, retail, manufacturing, and entertainment. They have the potential to revolutionize various aspects of our lives, enhance productivity, automate tasks, and drive innovation [23]. AI and IoT are two rapidly evolving technologies that have the potential to complement and enhance each other in various ways. When combined, AI and IoT create intelligent and connected systems that can generate valuable insights, automate processes, and enable smarter decision-making.

- **Data analytics:** IoT devices generate vast amounts of data from sensors, cameras, and other sources. AI algorithms can be applied to analyze this data, identify patterns, and extract meaningful insights. AI techniques such as machine learning and deep learning enable predictive analytics, anomaly detection, and real-time data processing, helping organizations derive actionable intelligence from IoT-generated data [23].
- **Predictive maintenance:** IoT sensors can monitor the condition and performance of equipment or machinery simultaneously. By applying AI algorithms to this sensor data, patterns can be identified that indicate imminent failures or maintenance needs. Predictive maintenance models powered by AI and IoT enable proactive maintenance scheduling, reducing downtime, and optimizing maintenance costs [24].
- **Autonomous systems:** AI and IoT can be combined to create autonomous systems that operate without human intervention. For example, in smart homes, AI algorithms can learn from sensor data and user preferences to automatically adjust lighting, temperature, and other environmental factors. In transportation, AI-powered autonomous vehicles can utilize IoT data from cameras, radars, and other sensors to navigate and make decisions on the road [25].
- **Personalized experiences:** AI can leverage IoT data to deliver personalized experiences to users. For instance, in healthcare, AI algorithms can analyze data from wearable devices, health trackers, and medical records to provide personalized recommendations for fitness, nutrition, and treatment plans. In retail, AI can use IoT data to offer personalized product recommendations based on individual preferences and buying behavior [26].
- **Enhanced safety and security:** AI and IoT can work together to improve safety and security in various domains. IoT sensors and cameras can capture data, and AI algorithms can analyze that data in real-time to detect anomalies, identify

potential threats, and trigger alerts. This combination is valuable in applications such as surveillance, smart cities, and industrial safety [27].

- Edge computing: The combination of AI and IoT is particularly useful in edge computing scenarios. Edge devices, such as IoT sensors or gateways, can process and analyze data locally using AI algorithms. This reduces the need for transmitting large amounts of data to the cloud, improves response time, and enhances privacy and security [28].

However, integrating AI and IoT also presents challenges. These include data management and storage requirements, ensuring data privacy and security, managing the complexity of AI algorithms on resource constrained IoT devices, and addressing ethical considerations around AI decision-making. Overcoming these challenges requires careful planning, robust infrastructure, and adherence to best practices for AI and IoT deployments.

5.1 AI-based public safety applications

AI technologies significantly enhance public safety in smart cities by enabling efficient monitoring, predictive analysis, and rapid response capabilities. As illustrated in **Figure 3**, these applications utilize data from sensors, cameras, and communication networks to create safer urban environments.

AI-powered intelligent surveillance systems use computer vision to analyze real-time video feeds, identifying suspicious behavior, unauthorized access, and potential threats. These systems can recognize faces, detect abandoned objects, and even

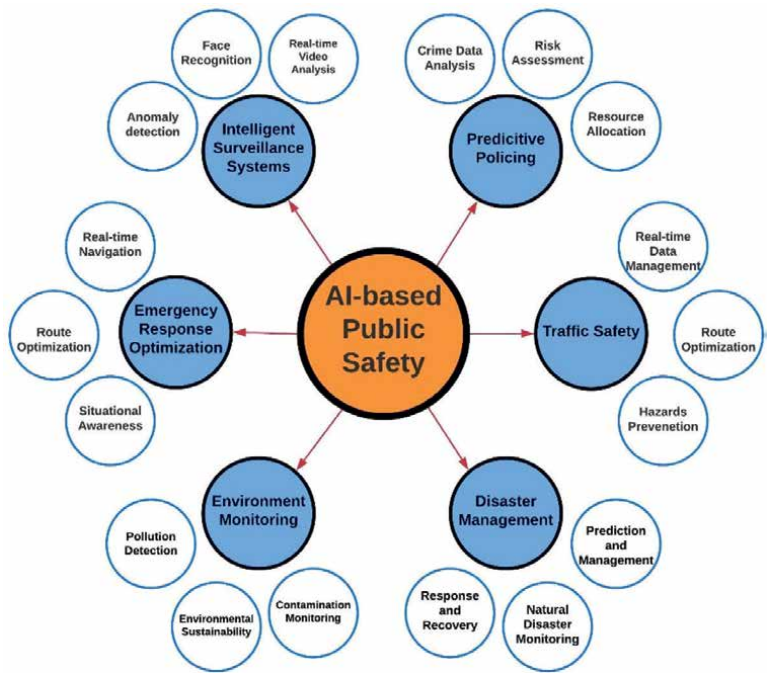


Figure 3.
AI-based public safety applications.

predict escalating conflicts in crowded areas. Automated alerts allow law enforcement to respond swiftly, reducing reliance on manual monitoring and increasing the effectiveness of urban security networks.

- Predictive policing leverages machine learning to analyze historical crime data, environmental factors, and demographic information, enabling authorities to forecast high-risk areas and times for criminal activities. This helps allocate resources effectively and implement preventive measures, such as increased patrolling or community outreach, reducing crime rates while optimizing law enforcement efforts [29].
- AI enhances emergency response optimization by streamlining dispatch systems, analyzing emergency calls for critical keywords, and prioritizing incidents for immediate attention. AI-driven route optimization ensures emergency vehicles navigate the fastest and safest paths, minimizing response times. During disasters, AI synthesizes data from multiple sources to provide situational awareness, aiding responders in deploying resources where they are needed most [30].
- In disaster management, AI models predict and monitor natural disasters by analyzing data from environmental sensors, weather reports, and satellite imagery. These systems can forecast floods, earthquakes, and hurricanes, providing early warnings to residents and enabling efficient evacuation plans. Post-disaster, AI-driven assessments of damage help allocate relief resources and prioritize recovery efforts.
- AI contributes to traffic safety by dynamically managing traffic flow using real-time data from road sensors and cameras. Intelligent systems adjust traffic signals to prevent congestion, identify hazardous conditions like accidents or road obstructions, and ensure smoother commutes. These measures reduce accidents and improve emergency vehicle mobility during critical situations [31].
- Environmental monitoring powered by AI integrates data from air and water quality sensors to detect pollution levels, hazardous materials, or contamination events. Alerts are sent to authorities, allowing for timely interventions to mitigate health risks. This proactive approach supports public health and environmental sustainability in urban settings [32].
- AI-driven community engagement platforms empower citizens by offering mobile apps that enable incident reporting, access to real-time safety updates, and emergency alerts tailored to specific regions. These apps enhance public participation in safety initiatives, fostering a collaborative approach to maintain security and ensuring timely responses to emerging issues [33].

By integrating these AI-based public safety solutions, smart cities create more secure and efficient environments. While these technologies bring numerous benefits, addressing challenges like data privacy, ethical concerns, and the potential for bias is essential to ensure equitable and responsible implementation.

5.2 Challenges to deploy AI in public safety

Deploying AI in public safety faces several challenges that complicate its integration into critical systems. One of the foremost issues is ensuring the quality and accessibility of data. AI systems depend on vast amounts of accurate data for training and operation, but data fragmentation among agencies, incomplete or biased datasets, and privacy concerns hinder their effectiveness. Sensitive information like surveillance footage or health records may be restricted due to privacy laws, limiting access to comprehensive datasets necessary for robust AI models.

Ethics and privacy concerns also present significant challenges. AI systems, such as facial recognition tools, can unintentionally reinforce biases present in the data they are trained on, leading to discriminatory outcomes. Surveillance systems risk infringing on privacy rights, particularly in areas with insufficient regulations. Furthermore, the lack of transparency in AI decision-making processes raises accountability issues, making it difficult to explain or justify decisions that directly impact individuals' lives [34].

Technical limitations are another hurdle in deploying AI for public safety. AI systems must achieve high accuracy and reliability, especially in critical applications like emergency response and predictive policing. False positives or negatives can have severe consequences, such as wrongful arrests or failure to detect threats. Additionally, real-time data processing and adaptability in unpredictable scenarios remain technical challenges, as AI models may struggle to operate efficiently during novel emergencies or changing threat landscapes [35].

The legal and regulatory environment for AI in public safety is often inconsistent or underdeveloped, creating confusion and slowing adoption. Without standardized regulations, organizations face difficulties ensuring compliance with data protection laws and other legal requirements. Accountability for AI errors, such as wrongful actions based on algorithmic outputs, is unclear, complicating liability and trust in these systems [36].

Public trust and acceptance are essential for successful AI deployment in public safety, yet skepticism often undermines adoption. Concerns about misuse, overreach in surveillance, and potential government overcontrol generate fear and resistance. High-profile failures of AI systems further erode public confidence, while a lack of understanding about the benefits of AI applications leaves communities hesitant to embrace these technologies [37].

Resource and cost constraints pose significant barriers. Developing and maintaining AI systems requires substantial financial investment, which can strain public safety budgets. Many organizations also face skill gaps, lacking personnel with the technical expertise needed to manage AI systems effectively. Infrastructure requirements, such as high-speed internet and cloud storage, may be inadequate in certain regions, limiting the scalability of AI solutions in public safety. By addressing these challenges systematically, organizations can deploy AI responsibly, ensuring it enhances public safety while maintaining ethical standards, legal compliance, and public trust [38].

6. Discussion

The rapid adoption of Internet of Things (IoT) technologies in smart cities has introduced numerous benefits, enhancing urban efficiency, sustainability, and

connectivity. However, alongside these advancements, several unintended consequences and ethical concerns have emerged, posing significant challenges to privacy, security, and societal well-being. Issues such as data privacy violations, algorithmic bias in decision-making systems, and cybersecurity vulnerabilities have raised questions about the responsible implementation of IoT infrastructure. Additionally, the socio-economic implications of smart technologies, including disparities in digital access and potential job displacement, highlight the need for equitable development strategies. Beyond ethical and social concerns, the impact of IoT on public health, particularly regarding electromagnetic radiation exposure and the increasing reliance on AI-driven healthcare systems, demands careful evaluation. This discussion explores these risks, emphasizing the importance of regulatory frameworks, ethical guidelines, and security measures to ensure that IoT-enabled smart cities develop in a safe, fair, and sustainable manner.

6.1 Potential unintended consequences

The integration of IoT in smart cities presents several unintended consequences, including privacy concerns, algorithmic bias, cybersecurity risks, and socio-economic disparities. Privacy concerns arise due to the extensive collection of personal data from smart devices, traffic cameras, and public surveillance systems. Without robust data protection regulations, sensitive information can be accessed, misused, or even sold without the knowledge or consent of individuals. This raises ethical questions regarding transparency and user control over personal data.

Algorithmic bias is another significant challenge, as AI-driven decision-making systems in smart cities may reflect the biases present in their training data. Biased algorithms can lead to unfair treatment in areas such as law enforcement, traffic control, and resource allocation, disproportionately affecting marginalized communities. Without proper oversight and diverse data representation, AI-powered solutions may perpetuate social inequalities rather than mitigate them.

Cybersecurity risks also escalate with the increasing reliance on IoT technologies. Many connected devices have weak encryption protocols or outdated security mechanisms, making them susceptible to hacking attempts. Cybercriminals could exploit vulnerabilities to disrupt essential city services, such as power grids, transportation networks, and healthcare systems. The potential for large-scale cyberattacks, including ransomware incidents targeting urban infrastructure, poses a critical security threat to smart city developments.

Additionally, IoT-driven urban innovations may deepen socio-economic disparities. Wealthier communities with better access to smart technologies benefit more from improved services, while lower-income neighborhoods may struggle with limited access to digital infrastructure. Moreover, the automation of certain jobs due to AI and IoT could lead to workforce displacement, exacerbating economic inequalities if adequate reskilling programs are not implemented.

6.2 Ethical concerns

Data security is a pressing ethical concern in IoT-enabled environments. Ensuring secure storage and encryption of data is crucial to prevent unauthorized access and breaches. Organizations must adopt transparent data policies that provide users with control over their personal information, ensuring compliance with privacy regulations such as the General Data Protection Regulation (GDPR) and the California

Consumer Privacy Act (CCPA). Without strict security measures, IoT devices could become an entry point for cybercriminals, leading to identity theft, financial fraud, and unauthorized surveillance.

AI-driven surveillance in smart cities raises ethical dilemmas regarding privacy and civil liberties. While AI-powered security systems can enhance crime prevention and traffic monitoring, they also pose risks of mass surveillance and government overreach. The misuse of facial recognition and behavioral tracking technologies could lead to violations of human rights, particularly if these tools are employed for unwarranted monitoring of citizens. Ethical governance frameworks, including independent oversight and public participation in decision-making, are necessary to balance security needs with individual freedoms.

7. Conclusion

This study highlights the pivotal role of IoT, AI, and big data analytics in shaping smart cities that prioritize health and safety. By examining successful implementations such as real-time air quality monitoring, AI-driven emergency response systems, and predictive healthcare services, it is evident that these technologies significantly contribute to creating safer and healthier urban environments. Despite the promising advancements, challenges related to scalability, data privacy, and equitable access remain critical barriers to full implementation. To address these, strategic urban planning must incorporate robust policies and frameworks that foster inclusivity, sustainability, and resilience. Ultimately, by leveraging technological innovations and adopting a holistic approach to urban development, cities can transform into thriving, technology-driven ecosystems that enhance public well-being and quality of life.

The integration of IoT technologies in smart cities has introduced significant advancements in urban efficiency, resource management, and connectivity. However, as highlighted in the discussion, these advancements come with unintended consequences that must be addressed to ensure ethical and sustainable deployment. Privacy concerns remain a pressing issue, as the mass collection and processing of data increase the risk of surveillance, data breaches, and unauthorized access. AI-driven decision-making also raises concerns about algorithmic bias, which can lead to discriminatory practices in law enforcement, public services, and economic opportunities. Without proper regulatory oversight, these issues could undermine public trust in smart city initiatives.

Cybersecurity vulnerabilities further complicate the implementation of IoT technologies. Many connected devices lack robust security protocols, making them susceptible to cyberattacks such as malware, ransomware, and unauthorized intrusions. These threats not only compromise individual privacy but also pose risks to critical city infrastructure, including transportation systems, power grids, and healthcare services. Ensuring the security of IoT ecosystems requires stringent cybersecurity regulations, real-time monitoring, and collaboration between governments, private sector stakeholders, and cybersecurity experts.

Beyond technological risks, the socio-economic implications of IoT in smart cities must be carefully considered. The digital divide remains a significant barrier, as lower-income communities often lack access to high-speed internet, smart devices, and the necessary digital literacy skills to benefit from IoT innovations. Additionally, the automation of jobs in transportation, retail, and manufacturing industries due to AI-driven processes could lead to increased unemployment if reskilling and

workforce transition programs are not prioritized. Addressing these disparities is essential to ensure that smart city developments are inclusive and equitable.

Public health risks associated with IoT adoption must not be overlooked. The widespread deployment of 5G networks and connected sensors raises concerns about prolonged exposure to electromagnetic radiation, the long-term effects of which are still being studied. Additionally, the increasing reliance on AI in healthcare could lead to over-dependence on automated systems, reducing the role of human expertise in medical decision-making. While AI can enhance diagnostics and treatment recommendations, it should complement, rather than replace, human oversight in healthcare systems.

To mitigate these challenges, a multi-stakeholder approach is necessary. Policymakers must implement stricter data privacy laws, enforce ethical AI usage, and promote digital equity. City planners should prioritize inclusive infrastructure development, ensuring that smart city benefits reach all communities. Technology developers must adopt privacy-by-design principles, strengthen IoT security, and enhance the transparency of AI algorithms. By addressing these concerns through proactive policy measures and ethical technological development, smart cities can evolve into sustainable, secure, and socially responsible environments.

The future of IoT in smart cities depends on a balanced approach that maximizes benefits while minimizing risks. While the potential for increased efficiency and innovation is immense, it is crucial to prioritize privacy, security, fairness, and public well-being. Only through responsible governance, ethical AI practices, and continued research into the socio-economic and health impacts of IoT can smart cities achieve their vision of creating a better, more connected world for all citizens.

Author details

Ahmed Hassebo
CUNY NYC College of Technology, Brooklyn, NY, USA

*Address all correspondence to: ahmed.hassebo10@citytech.cuny.edu

IntechOpen

© 2025 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. 

References

- [1] World Population Prospects 2022. Dept. of Economic and Social Affairs, Population Division. New York: The United Nations; 2022
- [2] World Urbanization Prospects 2018. Dept of Economic and Social Affairs, Population Division. New York: The United Nations; 2018
- [3] Keshav K, Pramod B, Vineet K. Smart cities market statistics: 2030. Allied Market Research. 2022
- [4] Lanvin B. Smart City index 2023. In: IMD World Competitiveness Center (WCC). Lausanne; 2023
- [5] Statista. Smart cities: Market data & analysis. 2024. Available from: <https://www.statista.com/study/146061/smart-cities-market-data-and-analysis/> [Accessed: June 2024]
- [6] Statista. Forecast on the degree of urbanization in the United States from 2000 to 2050. 2023. Available from: <https://www.statista.com/statistics/678561/urbanization-in-the-united-states/> [Accessed: January 2024]
- [7] Statista. Number of Internet of Things (IoT) Connected Devices Worldwide from 2019 to 2021, with Forecasts from 2022 to 2030; 2022
- [8] Global IoT market size. IoT Analytics. 2023. Available from: <https://iot-analytics.com/iot-market-size/>
- [9] Hassebo A. Commercial 4G LTE Cellular Networks for Supporting Emerging Mission-Critical IoT Applications. New York: ProQuest Dissertations Publishing; 2018
- [10] Tealab M, Hassebo A, Dabour A, AbdelAziz M. Smart cities digital transformation and 5G—ICT architecture. In: 2020 11th IEEE Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON). New York; 2020
- [11] Hassebo A, Rezk A, Ali MA. A hybrid uplink scheduling approach for supporting mission-critical smart grid applications in commercial 4G cellular networks. In: 2018 9th IEEE Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON). New York; 2018
- [12] Rodriguez J. Fundamentals of 5G Mobile Networks. New York: John Wiley & Sons, Ltd; 2015
- [13] Hassebo A, Tealab M. Global models of smart cities and potential IoT applications: A review. MDPI IoT. 2023;**4**(3):366-411
- [14] Schiavo F, Magalhães C. Smart sustainable cities: The essentials for managers' and leaders' initiatives within the complex context of differing definitions and assessments. Smart Cities. 2022;**5**(3)
- [15] Basford PJ, Bulot FMJ, Apetroaie-Cristea M, Cox SJ, Ossont SJ. LoRaWAN for smart city IoT deployments: A long term evaluation. MDPI Sensors. 2020;**20**(3)
- [16] Liu Z, Wu J. A review of the theory and practice of smart City construction in China. Sustainability. 2023;**15**(9)
- [17] Kociuba D, Sagan M, Kociuba W. Toward the smart city ecosystem model. Energies. 2023;**16**(6)
- [18] Mańka-Szulik M, Krawczyk D, Wodarski K. Residents' perceptions of

challenges related to implementation of smart city solutions by local government. Sustainability. 2023;15(11)

[19] Yuloskov A, Bahrami M, Mazzara M, Kotorov I. Smart cities in Russia: Current situation and insights for future development. Future Internet. 2021;13(10)

[20] Yigitcanlar T, Xia B, Cortese T, Sabatini-Marques J. City 4.0: Digital transformation of urban settlements. Sustainability. 2024;16(2)

[21] Hassebo A, Tealab M, Hamouda M. From a traditional city to a smart city: The measurement of cities' readiness for transition, Egypt as a case study. Urban Science. 2024;8(4)

[22] Hassebo A, Ali MA. Robust cellular connectivity-based smart LED street lighting system: A platform for innovative mission critical smart city IoT applications. In: 11th IEEE Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON). New York; 2020

[23] Gandomi AH, Chen F, Abualigah L. Big data analytics using artificial intelligence. MDPI Electronics. 2023;12(4)

[24] Hrnjica B, Softic S. Explainable AI in manufacturing: A predictive maintenance case. In: IFIP International Conference on Advances in Production Management Systems (APMS). Novi Sad, Serbia: Springer Nature

[25] Wang G, Ai J, Mo L, Yi X, Wu P, Wu X, et al. Anomaly detection for data from unmanned systems via improved graph neural networks with attention mechanism. MDPI Drones. 2023;7(5)

[26] Gallo C. Artificial intelligence for personalized genetics and new drug

development: Benefits and cautions. MDPI Bioengineering. 2023;10(5)

[27] Lee S. Foreword to the special issue on advances in secure AI: Technology and applications. MDPI Applied Sciences. 2022;12(19)

[28] Hu Y, Gong L, Li X, Li H, Zhang R, Gu R. A carrying method for 5G network slicing in smart grid communication services based on neural network. MDPI Future Internet. 2023;15(7)

[29] Sarzaeim P, Mahmoud Q, Azim A, Bauer G, Bowles I. A systematic review of using machine learning and natural language processing in smart policing. Computers. 2023;12(12)

[30] Garrido N, González-Martínez F, Losada S, Plaza A, del Olmo E, Mateo J. Innovation through artificial intelligence in triage systems for resource optimization in future pandemics. Biomimetics. 2024;9(7)

[31] Robotto A, Barger C, Marchesi L, Racca E, Brizio E. Innovative tools to contrast traffic pollution in urban areas: A review of the use of artificial intelligence. Air. 2024;2(4)

[32] Felici-Castell S, Segura-Garcia J, Perez-Solano J, Fayos-Jordan R, Soriano-Asensi A, Alcaraz-Calero J. AI-IoT low-cost pollution-monitoring sensor network to assist citizens with respiratory problems. Sensors. 2023;23(23)

[33] Nechesov A, Ruponen J. Empowering government efficiency through civic intelligence: Merging artificial intelligence and Blockchain for smart citizen proposals. Technologies. 2024;12(12)

[34] Dhirani L, Mukhtiar N, Chowdhry B, Neue T. Ethical dilemmas and privacy

issues in emerging technologies: A review. *Sensors*. 2023;**23**(3)

[35] Espina-Romero L, Gutiérrez Hurtado H, Ríos Parra D, Vilchez Pirela R, Talavera-Aguirre R, Ochoa-Díaz A. Challenges and opportunities in the implementation of AI in manufacturing: A bibliometric analysis. *Sci*. 2024;**6**(4)

[36] Kirwan B. The impact of artificial intelligence on future aviation safety culture. *Future Transportation*. 2024;**4**(2)

[37] Kovari A. AI for decision support: Balancing accuracy, transparency, and trust across sectors. *Information*. 2024;**15**(11)

[38] Tominc P, Oreški D, Čančer V, Rožman M. Statistically significant differences in AI support levels for project management between SMEs and large enterprises. *AI*. 2024;**5**(1)

Harmonizing Smart Education in Smart Cities

Safia Nahhas

Abstract

Smart education is an essential enabler of a smart city's sustainability and innovation. At the same time, smart education can enormously benefit from the smart city's environment to realize its potential. Nonetheless, most of the research on smart education has been done separately from the smart cities context. The literature demonstrated the need to conduct more studies on smart education along with smart city environments. There is a need to develop the incorporation of smart education in smart cities. The semantic web is an important candidate for playing this role due to its features, such as interoperability and connectivity. Based on that, we identified the characteristics of smart education. Accordingly, we proposed a framework and mapping between the required ontologies using the semantic web in order to actualize the features of smart education and harmonize it with the context of smart cities. As a result of this harmonization between smart education and smart cities, the opportunity to develop more creative applications and solutions will be boosted. Additionally, the provided conceptuality will facilitate building upon other applications. More connections between smart education and industry will arise based on the suggested framework and mapping. Eventually, all of that will support smart cities' sustainability.

Keywords: smart education, smart city, semantic web, mapping ontology, sustainability

1. Introduction

There are mutual benefits between smart education and smart cities. Smart education needs a smart environment to actualize its features, and smart cities need smart education to maintain sustainability and creativity. Smart education is an essential element of smart cities [1] and one of its targeted developments [2]. Smart education targets various segments of citizens, which leads to smart citizens. Additionally, education contributes to the growth and social development of smart cities [3]. It helps to empower individuals and enable a more active involvement in smart city initiatives [4]. Smart citizens are an integral part of smart cities [5]. Based on the analysis the authors of [6] made, building smart cities is becoming more focused on citizen-oriented aspects than on infrastructure or technology. The focus shifted from

hardware facilities to social infrastructure (people and social capital) and the availability and quality of knowledge communication [6]. According to [5], investments in human resources and education are part of the smart city action plan. Authors of [7] provided a noteworthy conclusion that city intelligence is a result of citizen engagement. Smart cities emphasize innovation, knowledge creation, information sharing, and digitalization, according to [5]. Smart education is an essential enabler of the first three features (innovation, knowledge creation, and information sharing).

Many studies indicate that education can help innovation and creativity in smart cities [2, 6, 8–13], thereby enhancing their sustainability [14–17]. For example, authors of [14] stated that “it appears that the concepts of education, of sustainable development and smart city are interconnected concepts and complement each other with the ultimate goal of achieving the prosperity of a city.” As part of their efforts to become smart cities, several cities have integrated education [18]. Authors in [19, 20] provided educational examples in smart cities such as Barcelona, Amsterdam, and Wuhan. The added advantages of a smart city are manifested in the form of a higher level of providing knowledge resources [21].

One of the fundamentals of smart education is improving competencies. At the same time, knowledge and competencies are essential components of the future smart cities [21]. Researchers of [13] argued that initiatives for smart cities should provide investments for ongoing education and training. In smart cities, businesses and academic institutions ought to prepare to update their approaches for involving citizens in education and services in light of the rapidly shifting global market [17]. According to [22], skills gaps are one of the five primary issues that smart city projects will face during implementation, and it is recommended to “accelerate and popularize education on related fields.” Skills, workforces, and educated individuals are features of smart cities, according to [23]. “Developing an economy based on knowledge and innovation” is mentioned in [14] as a European strategy. Smart learning could be an essential tool for bridging the gap between educational systems and the experiences of citizens [6]. All of this data indicates the importance of interconnection between education and other smart city sectors to facilitate the preparation of competent individuals.

Technologically, intelligent cities mean interconnected cities [1, 24]. Authors of [25] stated that “The use of smart computing technologies to make the critical infrastructure components and services of a city—which include city administration, education, healthcare, public safety, real estate, transportation, and utilities—more intelligent, interconnected, and efficient.” Data from one service’s information system can be used by another for their own purposes. This eliminates duplication of expenses, guarantees information availability, and brings about true efficiency [26]. Connected data leads to smarter information systems, including smarter education systems. Interconnectivity among learning environments, in particular, enables learning across several contexts and situations [27]. Smart Cities connectivity facilitates the creation of expert networks to ease communication and cooperation among smart citizens [28].

A prominent candidate for interconnection and interoperability to support smart education in smart cities is the semantic web. The semantic web can play a significant role in an ecosystem, such as in smart cities and smart education, where data comes from various sectors and sources in a variety of formats. Cities are naturally rich in concepts from many facets of life, and the semantic web can reflect and convey this diversity [29].

According to [29], “The recent vision of smart cities tends to move from vertical silos to horizontal cross data models. Cities’ domains are related to each other

and achieving interoperability among them leads to exchange data and to advanced services that raise the opportunities of semantic web in smart cities.” Along the same line, authors of [5] mentioned, “Other terms we usually find that denote smart city subsystems are the ‘silo’ and the ‘vertical market’. In the ‘silo’ perspective, these entities do not communicate with each other, which there are clear benefits from interoperability, information, and knowledge transfer.” Semantic web technologies facilitate sharing knowledge, and that is exactly what smart education pursues. Both smart cities and smart education encourage data transparency and openness, which can be significantly supported by the semantic web. Authors of [30] indicated that a recent research trend and significant e-learning problem is how to make learning systems intelligent. They mentioned the semantic web as a popular approach to address this issue. Additionally, according to [31], in order to facilitate the scalable and cross-domain development of smart applications, smart cities need the assistance of context-aware and enriched semantic descriptions. Integrating data across smart city sectors could lead to beyond the dimensions of creative applications. In order to offer a formal specification of shared conceptualization, semantic interoperability is also needed [32]. The review that was conducted by the authors of [33] reached the conclusion that “the use of smart and open data is indeed present in the context of smart cities, mainly addressing issues regarding integration and analysis to generate useful information. Among the approaches present in the literature, the most outstanding was the use of semantic technologies to treat and connect data from heterogeneous sources.”

However, the majority of research on smart education has been done in isolation of smart cities. The literature showed the need to integrate smart education in smart cities. For example, in [34], the authors stated that “However, no theoretical or practical attempts are found in the literature to establish effective links between TEL (Technology-Enhanced Learning) and smart cities”; “The literature review has found that smart city education is an emerging area” [35]; and “In order to utilize smart learning in upgrading of the city’s soft power, the government should integrate smart learning environment into the design of the smart city, and to use smart learning as one of the indicators for assessing smart city” [6]. Smart education needs a smart environment. Smart cities would offer many environmental requirements for smart education. Therefore, providing smart education solutions within the framework of smart cities is very effective. Education, in particular, has connections to the various sectors of smart cities since it will qualify individuals in these fields and will solve the research and innovation issues in smart cities. Integrating smart education in smart cities will facilitate cross-domain development. On the other side, smart cities need solutions to stay sustainable, and incorporating smart education would result in smart citizens who can greatly contribute to the sustainability of smart cities. Authors of [7] indicated, “The problem is related to the applications’ concepts and urban functions, rather than weaknesses in computer power, programming skills, data sources, data analytics, modeling, or any other aspects of the technology stack used in smart city solutions.”

Considering that, in this work we thoroughly studied the characteristics of smart education. Accordingly, as **Figure 1** shows, we leveraged the semantic web to suggest a framework and mapping between the relevant ontologies to harmonize smart education in the context of smart cities. Achieving harmony between smart education and smart cities leads to reaching their best potential and helps to actualize smart education features.

For instance, developing revolutionary applications and solutions based on integrated data, such as offering research solutions derived from patient data in the medical field.

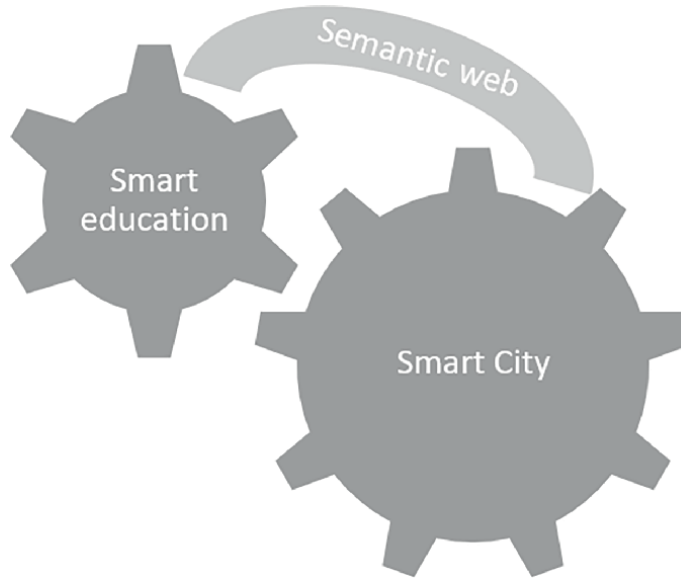


Figure 1.
Harmonizing smart education in smart cities by using the semantic web.

Another important dimension to be achieved based on our proposal is connecting with the industry. This connection will allow exchanging with smart education the requirements, qualifications, and expertise to support smart cities' sustainability. We suggested mapping between the smart city ontology and the ontologies of education, context, competencies, and other relevant ontologies. This mapping provides a conceptual level of connection that provides more radical solutions that other applications can build on. Additionally, the proposed mapping would result in a combined impact and communication across applications and systems. However, the suggested framework and mapping provide a starting point for exploiting the vital features of the semantic web, such as interoperability and connectivity, in integrating smart education in smart cities. The proposed solution is based on harnessing existing smart city solutions to integrate smart education, which is new to the field of smart education. To the best of our knowledge, this is the sole research effort that addresses all of these dimensions of integrating smart education into smart cities through the use of semantic web features and the mapping among ontologies to realize smart education features.

The rest of the study is organized into the following sections. The methods are presented in Section 2. Section 3 highlights the smart education characteristics. In Section 4, the reasons to choose the semantic web to harmonize smart education in smart cities are articulated. The proposed framework is presented in Section 5, and the suggested mapping ontologies are detailed in Section 6. Hence, Section 7 provides a discussion of the study. Lastly, Section 8 concludes the study and outlines the potential implications and future work.

2. Methods

We used [36] as an overall guideline in achieving this research. In light of our previous studies, we had many indications regarding the important contribution

that the semantic web provides in smart cities, generally due to its interoperability and connectivity. Thus, we concentrated on smart education in smart cities specifically and took the following steps. We started by researching the advantages that smart education can gain by exploiting smart city environments using the semantic web standards. We conducted thorough research but found a few studies that tackle the topic of smart education in the context of smart cities, particularly. We extracted and determined the characteristics of smart education from extensive and comprehensive references. Then, we touched on each smart education characteristic separately and provided some examples of how it benefits from the semantic web. In addition, we examined the relationships among smart education characteristics. We looked for the most quality attributes that smart education needs in a smart city. Based on these indications, we provided a general framework that considered the future modern perspective of education and its interactions with smart city sectors. We took further steps in realizing this framework and suggested mapping among the smart city ontology and other educational, training, and contextual ontologies. To achieve that, we did broad research on the key ontologies. We used the most relevant, referenced, and prevalent ontologies in each field. We chose the Smart City Ontology (SCO) ontology rather than other available ontologies for additional criteria. SCO is a smart city ontology that was not built for a specific city or specific field. It covers the aspects of smart city visions and is significantly compatible with smart education requirements. User-centric smart education's feature aligns well with SCO's emphasis on human involvement. We suggested mapping with other existing ontologies as a further iteration based on emerging needs or creating new ones if there is a necessity. Depending on the situation, various techniques are implemented for actual mapping. Main techniques that are used in mapping are (owl:subclassOf, rdfs:subPropertyOf, owl:sameAs, owl:inverseOf, owl:equivalentClass, and owl:equivalentProperty, rdfs:seeAlso, skos:exactMatch, skos:broadMatch, skos:narrowMatch, skos:closeMatch, and skos:relatedMatch, owl:imports) [37–39]. For example, making teaching concepts from educational ontologies a subclass of the “Activity” class in the SCO ontology.

3. Smart education characteristics

In order to enable smart education in smart cities and exploit smart cities' abilities, it is essential to determine the smart education characteristics and requirements. On the other hand, doing so will help smart cities maintain their sustainability. The next sections detail smart education characteristics based on reviewing many studies in the field; see **Figure 2**.

3.1 Personalizing, adapting, and tailoring

One of the most important fundamentals of smart education is realizing the concepts of “people first” and learner as kernel [2] through user-centric models [40]. User-centric approaches are supposed to provide customized plans for students, as authors in [21, 34] gave examples. Customizing and tailoring are achieved by considering the user's needs, characteristics, interests, goals, preferences, skills, personal motivation, students' previous knowledge, styles, and behaviors of learning. Another vital aspect of personalization in education is personalizing the assessment and the content delivery [6], making process records [15], and providing control over the

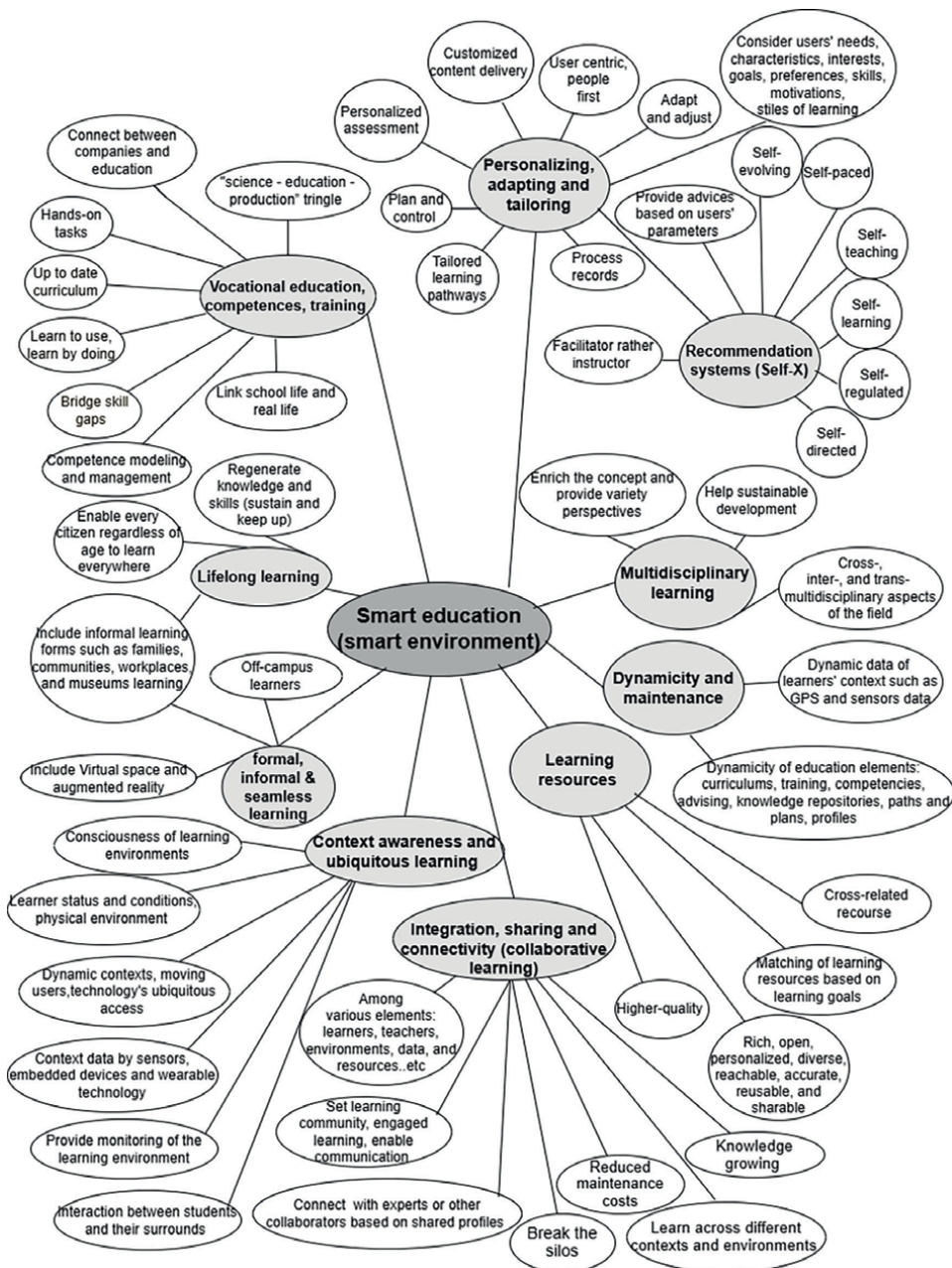


Figure 2.
Smart education characteristics.

user's learning [41]. Orienting education systems to adapt and adjust based on previous issues is crucial for personalizing education [1, 2]; furthermore, that leads to making learning "effective, efficient, and engaging" [42]. Many technologies play a vital role in reaching this view of personalizing education, especially on a large scale [43–45]. Here, the importance of harnessing smart city technologies for smart education manifests. One of the technologies that is mentioned frequently in this field of

research is the semantic web. Authors in [30] indicated that “Due to the advantages of the semantic web, it is widely used in adaptive educational systems and intelligent tutoring systems.” Each of, [15, 21, 22, 46, 47], provided personalized solutions with the aid of the semantic web. For example, the authors of [15] manifest that “the links between knowledge points based on semantic relationships can realize the personalized presentation of knowledge contents.” Researchers in [46] used ontologies to model the profiles of the learners based on their skills, interests, goals, and preferences. In [22], the authors used the Semantic Web Rule Language (SWRL) repository and ontologies to provide dynamic, tailored learning paths and suggest future learning steps. In [47], the EDUC8EU ontology and additional semantic technologies are used to offer each student a completely customized academic advising process that takes into account their personality, interests, past knowledge, and learning requirements. According to [21], MOMAMOOOC, a user-centric platform, is developed using semantic solutions to suggest high-level training goals based on the needs and cognitive state of learners by analyzing the information’s meaning rather than checking for keywords.

3.1.1 Recommendation systems

As an extension of the personalization feature, recommendation systems (intelligent recommendation [2]) are an important element of smart education. Recommendation systems provide learners with advice and suggestions at the right place and at the right time [1]. The advice is personalized based on the student parameters that are taken from learner models [48]. Furthermore, recommendation systems help to put learners on the track of self-reliance by applying several self-X concepts. Self-X could be self-directed [18, 34], self-regulated [46], self-teaching [1], self-learning [24], self-paced [24], self-evolving [27], and so on. Such a smart environment helps to alter the role of teachers from being instructors to being facilitators [15]. Recommendation systems can utilize existing semantic knowledge bases that are built based on personal ontologies such as Friend of a Friend (FOAF) and other resume ontologies to derive worthwhile personal information and provide better recommendations. As an example of research that used semantic technologies to provide intelligent recommendations, authors in [47] combined ontological techniques, fuzzy reasoning, and expert systems to give students recommendations for the next suitable learning step.

3.2 Vocational education, competences, training, and learning by doing

To sustain smart cities, eligible people are needed [6]. It is essential to empower the best education practices, including providing citizens with the skills they need to live in smart cities. “Science, education, and production” triangle is an idea that helps to have competent and trained people [26]. More connections and cooperation between universities and companies lead to more qualified people and sustainable, smart cities. Up-to-date reviewing and improving of the curriculum to fit the requirements of the industry and cities’ infrastructure will help to reach this view [49]. Additionally, more hands-on tasks and workforce experiences [49] are extremely helpful to engage students in real life. Vocational and professional learning (learning to use) and learning by doing are interesting concepts in this direction that are discussed in [2, 34]. The authors in [21] stated that “The Smart City of the Future will be more and more based on the synergic combination of knowledge and human capital.” Both [21, 22] emphasized the importance of leveraging smart technologies to achieve training goals in order to fill

skill gaps in smart cities. Competence modeling and management solutions are required to solve these issues. Researchers in [22, 21, 50, 51] touched on semantic solutions that can help to connect education and work. Interestingly, authors in [21] indicated that competence modeling can utilize the same information in different contexts, such as educational or work environments. Additionally, authors in [22] manifested how the semantic web helped them to tackle the problem of different stakeholders' understandings of terminology and descriptions of competency.

3.3 Lifelong learning

Citizens should keep up with the continuous evolution of smart cities [2]. Therefore, they need to regenerate their knowledge and skills; otherwise, their information and competencies will be out of date. Lifelong learning can immensely help to fulfill such a perspective [34]. By adopting the concept of lifelong learning, every citizen, regardless of age, will be able to learn everywhere, not only in schools [1, 14]. Smart city technologies can offer the chance to create such a smart environment that supports people's progress and development throughout their entire lives [17]. Lifelong learning is one of the forms of future education [49]. According to authors in [27], some forms of lifelong learning can include informal learning environments such as those found in schools, families, communities, workplaces, and museums. They indicated that "Learning in the community or the museum is a supplement to the classroom learning, because some specific knowledge or skills are more easily acquired in community and museum." [27] Using the semantic web helps to connect data from different sources and areas, which supports lifelong learning for all people, regardless of their fields.

3.4 Formal, informal education, and seamless learning

Different types of learning can be found in smart cities [2]. In addition to education received in schools, it may also occur virtually through home, work, community, or social learning environments [6]. Non-formal and informal education are essential enablers for lifelong learning [49]. The authors in [15] discussed that formal and informal learning in physical and virtual spaces is part of a smart learning environment that leads to realizing the concept of seamless learning. Therefore, in a smart education environment, learners can be off-campus learners [15]. Besides Massive Open Online Courses (MOOCs) and blended learning, the work-based learning stage is mentioned in [22], "where a pool of collaborators are identified willing to host learners during their work-based learning stage." In line with the mentioned environments, augmented reality, which replaces the desktop user interface with a 3D space of augmented classrooms, can play an important role in nontraditional learning [24]. The authors in [21] discussed that knowledge management is viewed as a fundamental component of the smart city of the future, and through the use of "unpredictable" resource links via potential paths on the Knowledge Graph, formal, non-formal, and informal learning difficulties can be addressed through the use of semantic approaches. The research in [52] details the impact of semantic technologies on different types of education.

3.5 Context awareness and ubiquitous learning

Context awareness is among the fundamentals of smart education [53]. In [1], context awareness in education (consciousness of learning environments) is defined

as “the ability of a system to understand or discover different contexts of the users within the process of learning and to implement the activity of the system with the user.” Another definition of context awareness and ubiquitous learning in [2] is “computer-supported learning paradigms that identify learners’ surrounding context and social situation to provide integrated, interoperable, pervasive, and seamless learning experiences.” Context awareness helps to detect the real-world learning status of learners, such as the learner’s location and time, environment, proximity, and situation [49]. Some technologies, such as eye movement, emotion computing, and motion capture technologies, can be utilized to monitor and keep track of the students’ progress and status [15]. In order to provide students with a comfortable physical environment, smart learning environments can use sensor technologies to monitor the air, temperature, light, sound, smell, and other physical environmental elements [15]. For instance, the learner’s position can affect how the learning is delivered in relation to their surroundings and can be used to organize cooperative learning activities by assigning students to groups according to where they are located [15]. Since users are mobile, the user’s context in smart cities is dynamic [1]. Because of this, informational services ought to be available to modern users wherever they are. At this point, the significance of ubiquitous learning becomes evident where there is ubiquitous access to technology. Learning will become more personalized as a result of contextual information and technology’s ubiquitous access. According to [54], contextual awareness can help to combine virtual learning with traditional learning environments. Additionally, authors in [55] indicated that full context awareness could be reached by integrating ubiquitous sensing devices, such as wearable technology like smart watches, brainwave detection, and emotion identification, with smart learning settings and the Internet of Things. Context awareness and ubiquitous learning systems contribute to providing monitoring of the learning environment, understanding learners’ conditions, providing independent learning, and other features [56]. Since the embedded objects can contain the source data, learners may not even be aware that education is taking place all around them [57]. Ubiquitous learning helps to realize the breadth of learning [27]. More about the aspects of context awareness and ubiquitous learning can be found in [58]. Context is crucial in education because smart learning involves students and their environment interacting in a meaningful way [1, 2]. Since the semantic web can understand the meaning of contexts, it can play an essential role in smart education. For example, as authors in [21] mentioned, the context in which the competencies are derived or requested to be used can define them; the existence of a competency in one context does not guarantee that it will be used in another area at the same performance level. Furthermore, as one of the semantic web’s primary strengths is interoperability, it can enable compatible functioning across learning resources and services with the user’s continuous movement.

3.6 Integration, sharing, and connectivity (collaborative learning)

Integration and connectivity between the various elements of education, such as learners, teachers, environments, data, and resources, contribute to the reach of smart education [6]. It helps to share data among users and facilitate collaborative learning. Smart learning environments can set up learning communities to ease communication and exchange among students [15]. According to [2], smart learning has three characteristics: easy, engaged, and effective. Engaged learning can be realized by offering the students the ability to communicate and cooperate with each other to achieve learning

outcomes. Interesting examples of employing ontology mapping to connect students with experts or other collaborators based on shared profiles were given by [21, 46]. The integration and connection process has a significant influence since smart education is not limited to schools and instead occurs in a variety of settings, including homes, workplaces, communities, and other environments. It will help students to learn across different contexts and environments [27] and break the silos [49]. The authors in [49] talked about a knowledge model that grows spirally by applying knowledge sharing among individuals. Interestingly, one of the smart city governance principles is sharing data [34]. Authors in [22] indicated that sharing knowledge among municipalities leads to reduced maintenance costs. They showed that the high interoperability achieved by using semantics leads to enabling information exchange among municipalities, academic advisers, learning object providers, localities, and collaborators. Authors in [33] stated that “semantic Web technologies and Linked Open Data principles provide a means for sharing knowledge about cities as physical, economical, social, and technical systems, enabling the development of smart city services.”

3.7 Learning resources

Typically, learning resources in smart education have additional features such as being rich [24], open [49], personalized [24, 30], offering equity to gain it [6], diverse, reachable, accurate, reusable, and shareable [2]. Moreover, higher-quality knowledge resources can be offered by smart cities [21]. Learning resources could be learning tools or learning content, as in the case of [46]. Learning objectives should guide the provision of learning resources in order to facilitate a range of learning activities; this is known as the matching of learning resources [2]. Authors in [2] indicate using semantic web technologies to facilitate retrieving and classifying the resource, improve the retrieval’s recall ratio and accuracy, and achieve flexible resource sharing, coupling, and reuse. Additionally, cross-related recourse is an interesting idea mentioned in [21] by using semantic web solutions as follows: “All semantic technologies allow for quickly finding cross-related material from large knowledge repositories, such as Wikipedia, YouTube, available MOOCs, Smart City-specific resources, etc.” Semantic web technology can help machines better understand the relationships and meanings of resources and knowledge. This feature opens the door to the potential for automatic resource semantic recommendations [30]. In [59], the authors proposed an architecture to provide mutual enrichment between traditional and informal learning resources by using semantic technologies.

3.8 Dynamicity and maintenance

The core idea behind smart cities is constant evolution. As a result, education needs to be relevant, dynamic, and maintainable. Curriculums [49, 60], training programs, competencies [21], academic advising and recommendations [47], knowledge repositories [46], learning paths and plans, learners’ profiles, such as learning goals and progress [46], and other educational components are all included in this dynamicity. A lot of movement data is coming in from GPS and sensors to help students with ongoing tasks or short-term objectives. This data is very dynamic [34]. As an example of a completely dynamic and changing knowledge space, the semantic model in [47] is represented. Additionally, researchers in [22, 46] touched on the efficiency of using the semantic web to provide dynamic and maintainable solutions for education, such as updated knowledge bases by using ontologies and reasoning.

3.9 Multidisciplinary learning

The United Nations Economic and Social Council's 2016 report on "Smart cities and infrastructure" (UNCTAD) suggested encouraging multidisciplinary learning [22]. There is a connection between interdisciplinary and sustainable development that allows for interaction between people and sustainable development goals [14]. Cross-, inter-, and trans-multidisciplinary aspects of the field indicated that the field's articles could come from a variety of domains, which could lead to difficulties in understanding the research approaches in the different fields [18]. One challenge is establishing a common language and a single concept for the various aspects of the domains. However, multidisciplinary could enrich the concepts and provide varied perspectives on the topic. Semantic web technologies are at the core of helping to mitigate such challenges and boost the multidisciplinary features.

4. Semantic web to harmonize smart education in smart cities

In the previous sections, several motivations are mentioned to choose the semantic web as a vital approach to fit in smart education in smart cities. We presented the characteristics and requirements of smart education. The use of the semantic web in each characteristic, along with its added value, is indicated. Additionally, the authors in [29] manifested the following characteristics of the semantic web in smart cities: interpretable and meaningful data, reliability of semantic description and representation, semantic reasoning, shared concepts and understanding, open standards and platforms, providing enrichment, data management, resource/service search and discovery, providing visualization, response to many quality attributes at varying levels, such as interoperability, scalability, real-time data, dynamicity, flexibility, adaptivity, transparency, and removing redundancy. We can observe that the demands of smart education are highly matched with semantic web abilities in smart cities. Furthermore, as we are discussing the harmonization of smart education in smart cities, we are discussing the variety of data sources and formats, which is at the core of the challenges that the semantic web can tackle. Authors in [49] stated that "It is a challenge for smart learning environments to collect these data about the learners and their environment from disparate sources in both physical and online components of the ubiquitous settings." In the next sections, further illustrations of the advantages of using the semantic web with smart education in smart cities will be shown.

5. General framework for smart education in smart cities

The contemporary perspective of education is to link it with the other city's sectors, since education will be in charge of supplying qualified personnel for those fields. On the other hand, smart city sectors will demand solutions from the education sector to solve their renewed challenges through research. The framework in **Figure 3** is proposed to pursue such a view of smart education in smart cities:

- Various cities' sectors format their required competencies based on competency and labor ontologies such as European Skills, Competences, Qualifications and Occupations (ESCO). The ESCO ontology, for example, is open, clear, and explicit and provides a shared understanding of labor

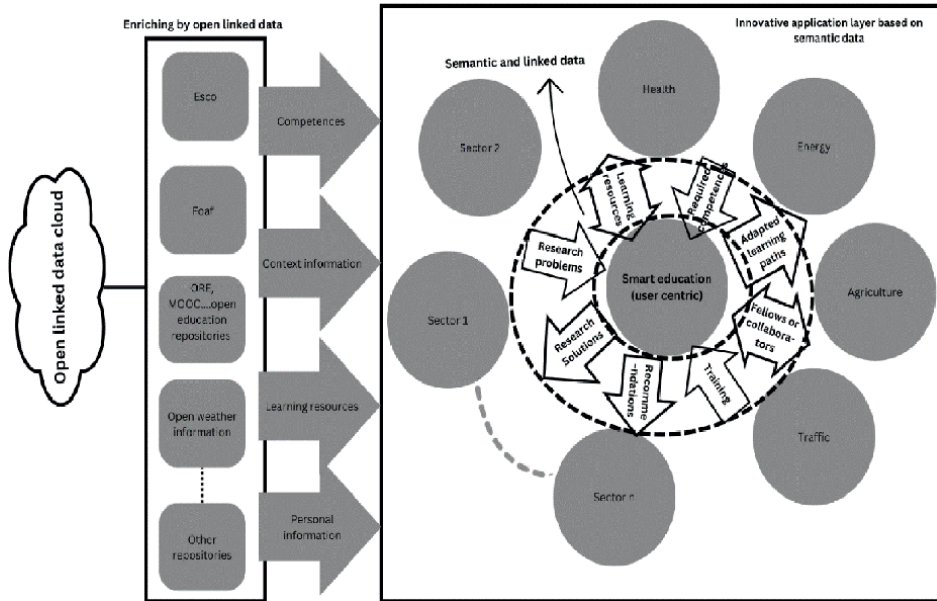


Figure 3.
General framework to harmonize smart education in smart cities.

competencies in the various fields. Education in the city will respond by providing courses and learning units based on the required competencies from the universities and the semantic open education repositories, such as MOOCs and others. Authors in [51] provided an example of a competency-based course model by using semantic technologies that can help to achieve that. For example, following ESCO will provide “competency narrower skill,” “competency broader skill,” “competency essential knowledge,” and “competency optional knowledge.” Course designers consider this important information in designing courses and providing relevant material. The competencies and the responded learning resources are dynamic; therefore, they should be updated easily and continuously. This point is available for all citizens, regardless of their age, place, and time. Microlearning materials with semantic annotations will assist in addressing learners’ individual concerns and in meeting the labor-required competencies more easily.

- Education requests that a city’s sectors offer training opportunities to learners who need to improve their skills or become more engaged in a particular subject. The “competency essential occupation” and “competency optional occupation” that are gained by following ESCO help in finding relevant training companies based on the mentioned occupations. Contextual information is to be considered to facilitate, for example, finding the closest training places and companies for learners. Using ontologies like the one described in [61] can improve trainees’ level in smart cities. On the other hand, regardless of age, workers across various city sectors request that education provide them with the most up-to-date information and patents in their fields of interest. Therefore, they can stay acquainted with the most recent findings, which will facilitate promoting lifelong learning and exploiting the latest knowledge.

- Based on common ontologies in each field, different city sectors formulate their arising challenges and problems, and education responds by offering research solutions.
- Education gathers a variety of context information with the help of open-linked data and ontologies like the one described in [62]. Context information could include the physical environment (temperature, humidity, etc.), the competencies and skills required in this territory's industry, learners' status, and so forth. Contextual information facilitates providing appropriate recommendations, adapting learning paths, and suggesting collaborators. To aid in personalization and adaptation in education, personal data formatted according to personal ontologies, like FOAF, in open-linked data can be utilized. Open datasets that offer real-time weather information are an example of environmental contextual information that can be utilized for this purpose.
- Besides education, other sectors can contribute to adding learning resources that include their accumulated expertise to enhance beginner learners' competencies in each field. Competences in ESCO can be linked to microlearning units that include daily expertise supplied by professionals and subject-matter experts.
- As dotted circles show that information is dynamic, the area between the two dotted circles in **Figure 3** represents semantic and linked data outcomes from the aforementioned points that can be used to create highly creative and intelligent applications. Because the data is interconnected and spans several city sectors, it will add other innovative dimensions to the application capabilities. For instance, linking the environmental conditions information, such as pollution, dust, high altitudes, and others, to the health sector in the region to know how those environmental conditions could affect some health issues like respiratory diseases, allergies, pressure, and so on. Furthermore, link that to the manufacturing sector to supply devices for those health issues, such as air purifiers, for example. In education, investigating the relationships between those environmental factors and the emerging health issues can be conducted. This shows the importance of providing interoperability information between the various city sectors.
- One of the characteristics of smart education is cross-, inter-, and trans-multi-disciplinary education. Multidisciplinarity helps study a subject from multiple different disciplines, while interdisciplinarity provides integration of viewpoints or ideas from other viewpoints to gain a deeper understanding of a complex issue. Transdisciplinarity goes a step further and involves practice besides science [63]. The proposed perspective that connects education with other city sectors can boost these concepts of education. For instance, the same terminology could be found across several sectors with different definitions. The semantic web will assist in providing context-based definitions, providing learners with many viewpoints on the same terminology.

The next section contributes to providing preliminary steps toward this framework by suggesting a mapping between relevant ontologies to harmonize smart education in smart cities.

6. Mapping key ontologies

To implement the smart educational ideas discussed in earlier sections by leveraging the semantic web, mapping relevant ontologies is one of the most important keys. Mapping ontologies facilitates communication and meaning across applications and systems. To achieve that, we did extensive searches on the most referenced, highly used, and relevant ontologies. We used Smart City Ontology (SCO) [5] as the core of the proposed mapping. Authors of SCO stated that SCO is “to help researchers and smart city developers identify areas in which smart technologies and solutions may improve the digital infrastructures and e-services that cities provide. Smart cities evolve by integrating digital and non-digital city elements. Identifying virgin areas of digital transformation may help to develop new smart city solutions for optimization of assets and the design of innovative e-services.” SCO’s emphasis on human engagement aligns well with the concept of user-centric smart education features.

Interestingly, SCO has many indicators that can measure different aspects of smart cities, such as Internet coverage, use of e-services, innovation enablers, activities, performance, and smart city ecosystems. Other ontologies, such as the Teaching Core Vocabulary Specification (TEACH), Courseware, LOCWD: A Vocabulary for Open Courseware Based on Linked Open Data Technologies, and AIISO: Academic Institution Internal Structure Ontology, for educational elements; ESCO and CBC: Competency-Based Course Ontology for competences [51]; TEO: Training Evaluation Ontology [61] for training; and Context Ontology [62] for context information, are candidate ontologies to map with SCO, as **Figure 4** shows. Contextual information such as environment, location and time, situation, and others can be gathered from several sources. Mainly, sensors are used for monitoring the air, temperature, light, sound, smell, noise, crowd, and other physical environmental elements. Other

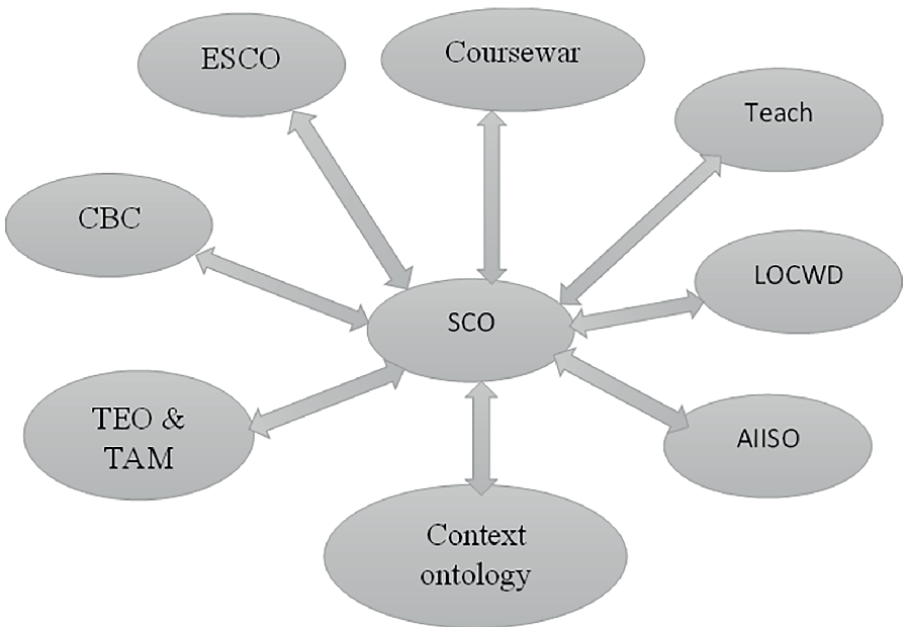


Figure 4.
Mapping key ontologies to harmonize smart education in smart cities.

sources of contextual information include embedded devices and sensing devices such as wearable technology like smartwatches, brainwave detection, emotion identification, and motion capture technology. Social media and linked data are also other important sources of personal and contextual data. SSN (Semantic Sensor Network) Ontology [64] is primarily used to deal with sensor data semantically and give them high-level specifications. RDFa, which is embedded in social media applications, is another technique to exploit contextual information in social media and deal with it semantically. **Table 1** presents mapping details between SCO ontology elements and the targeted smart educational principles.

SCO elements for mapping	Candidate elements from other ontologies	The targeted smart educational characteristic
“Community” class and its subclasses, such as communities of place, communes and collectives, activity-based elective communities, and virtual communities.	Students, teachers, and researchers.	• Attain collaborative learning. • Enhance physical and virtual connection among learning communities.
Human elements under the “Element” class.	Students, teachers, and researchers.	People-first principle.
“Area” and “Activity” classes under the “Element” class.	• Mainly universities, institutions, and schools as areas. Other places, such as work, homes, and museums, are also possible. • Mainly learning, teaching, and training as activities.	Appointing areas and activities helps immensely in providing personalization and appropriate recommendations.
“Ecosystem” class.	Education.	Provide an explicit shared concept.
“Digital space” (or smart environment) layer under the Architecture class.	Smart education environment.	To provide a digital technologies stack for a smart education environment.
“E-Service” class.	E-learning and educational e-services.	Express other modern educational styles, such as informal learning and ubiquitous learning, and facilitate connections among educational e-services.
“Digital-system-design” defines the essential characteristics of e-services and the data processes that underpin them.	Educational digital systems design.	Helps to provide designs for digital educational systems based on smart education principles.
“Data” class.	Educational data.	Helps to enrich, share, and connect data.
“Information and knowledge layer” under Architecture class: “Institutions trigger and manage knowledge flows, agreements between academia and producers, innovation funding and allocation of resources” [5].	Universities and institutions.	• Helps link universities and companies.

SCO elements for mapping	Candidate elements from other ontologies	The targeted smart educational characteristic
“Social-space” class under “Element”: this class is almost for occupations and professions.	Competences and training.	Helps to attain vocational education, competencies, and training.
“Environmental-context” covers the context of the environment and the natural resources.	Physical context.	Provide context information to help attain context awareness.
“Instrumentation-intelligence” is about collecting data from sensors, social media, and urban activities; analyzing it; and delivering information in real time, predictions, alerts, and more informed choices.	Physical and personal context.	• Provide context information to help attain context awareness. • Helps to provide personalization and adaptation.
“Empowerment-intelligence” “rests on improvements in human skills and know-how realized through a combination of institutional and digital means. It is an individual learning process, but when practiced on a massive scale across the entire city can produce great results.” [5]	Universities and institutions, competences, training, and learning resources.	Helps informal education, lifelong learning, vocational education, competencies, training, and learning by doing.
“Orchestration-intelligence” “is based on a large-scale division of work and integration of knowledge tasks that are distributed among the population, the institutions, and infrastructure of a smart city.” [5]	Universities and institutions, competences, training, and learning resources.	• Helps link universities and work. • Allows workplaces to contribute to providing learning resources.
“Challenge” class.	Educational challenges.	Helps to identify smart educational challenges explicitly.
“Planning” class where the smart city planning process takes place per vertical ecosystems.	Educational planning.	Helps to express smart educational plans explicitly.

Table 1.
Mapping between SCO ontology elements and the targeted smart educational principles.

7. Discussion

This study identified the various characteristics of smart education. By taking advantage of the smart city setting, we conceived a vital role that the semantic web can play to improve and realize smart education features. Therefore, we provided a general framework and initial mapping among the key ontologies in the relevant fields.

The mapping that we introduced provided a primal version to realize using the semantic web to harmonize smart education in smart cities. Future iterations are predicted to involve other ontologies according to emerging needs. However, this mapping offered the foundation and groundwork that could serve as the basis for future implementation processes. The conceptual interoperability that resulted from adopting shared and explicit concepts as applied in this mapping is expected to play an essential role in facilitating data management for smart education in smart cities. It helps to give formal representation and measures for smart education concepts. Since

we mapped with SCO, which connected with other aspects and sectors of the city, this will help in aligning and enriching with valuable knowledge sources for education. In fact, we found there is great compatibility between smart education needs and SCO foundations, which makes this mapping fruitful. This mapping can take a lot of the burdens needed for smart education systems by exploiting smart city infrastructure. Furthermore, we introduced mapping with other important ontologies for education, such as context and training ontologies. All of that resulted in a fertile environment for innovative educational e-services that boost smart education philosophies. Information such as competencies, training opportunities, context information, and real-time data that are essential for smart education would be more accessible through adopting this mapping. Exchangeable learning resources between education and other city sectors would be more realistic. Strengthening the connection between education and industry is also one of the fruits of this mapping.

To bridge the gap between real smart cities' problems and successful educational solutions, the proposed framework recommends employing ontologies to represent emerging challenges in each sector. Further investigation on ontologies that can facilitate this point is required to speed up requests and responses between the city sectors' challenges and education.

During our study of smart education characteristics, we found interesting correlations between several aspects of smart education. For instance, the personalization processes are related to context, competencies, learning resources, and dynamicity. It is required to take into account the context of each learner to provide personal learning resources based on the needed competencies dynamically. Considering the context and personal factors regularly requires high dynamicity. Since informal education and lifelong learning are significant learning enablers, they promote more self-X learning styles and autonomous learning with consideration of personal required competencies. Ubiquitous learning is linked to lifelong learning since it allows for everyone to study at all times, wherever, and regardless of age, seamlessly. Ubiquitous learning implies high connectivity and interoperability. Virtuality, augmented reality, and informal learning can facilitate collaborative learning and connecting with experts, peers, and collaborators to improve competencies. Competencies are related to context since they can be defined by the context in which they were extracted or by the setting in which they are to be applied. Sharing data is another form of informal learning.

The common factor among all these relationships is using technology to enable them. The semantic web is one of the technologies used to realize many smart education ideas. Since the suggested framework and mapping are based on the smart city setting and connections with other city sectors, they can help increase interconnection, dynamicity, and interoperability.

8. Conclusion

This study proposed a framework and a mapping between key ontologies in the context of smart cities to harmonize smart education using semantic web features. Few studies have examined smart education from this perspective. Moreover, using the semantic web to integrate smart education in smart cities provides many added values and combined features. Some of the expected implications of this study are as follows: Initially, it will facilitate greater convergence in order to achieve the characteristics of smart education. Additionally, increasing the opportunities for

providing more revolutionary applications and solutions as a result of the integration of data across the city's domains. As well as the conceptuality that has been supplied, it will make it easier to build upon other applications. The connection between smart education and industry would be clearer, easier, and more efficient. All of that will contribute to smart cities' sustainability. However, this work provided a starting point to use the semantic web in integrating smart education in smart cities. Additional works can be built upon it to utilize semantic web features and smart city context. As future work, there are smart cities' frameworks, such as OneM2M, M3, and Cityplus, that are worth utilizing to synergize smart education in smart cities. More specifically, through analyzing each characteristic of smart education separately, a greater and deeper focus might be given to improving it. Investigating how every characteristic of smart education can benefit from smart city environments and semantic web capabilities.

Author details

Safia Nahhas

Faculty of Computing and Information Technology, King Abdulaziz University,
Jeddah, Saudi Arabia

*Address all correspondence to: nahhas.safia@gmail.com

IntechOpen

© 2025 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. 

References

- [1] Dumančić M. Smart education in smart city and student model. In: Conference Proceedings of eLearning and Software for Education (eLSE). Bucharest, Romania: Carol I National Defence University Publishing House; 2019
- [2] Liu D, Huang R, Wosinski M. Characteristics and framework of smart learning. In: Smart Learning in Smart Cities. Lecture Notes in Educational Technology. Singapore: Springer; 2017. DOI: 10.1007/978-981-10-4343-7_3
- [3] Letaifa SB. How to strategize smart cities: Revealing the SMART model. Journal of Business Research. 2015;**68**(7):1414-1419
- [4] Hudson L et al. Supporting urban change: Using a MOOC to facilitate attitudinal learning and participation in smart cities. Computers in Education. 2019;**129**:37-47
- [5] Komninos N, Panori A, Kakderi C. The smart city ontology 2.0. In: URENIO Research Discussion Papers. Greece: Urban and Regional Innovation Research (URENIO); School of Engineering at the Aristotle University of Thessaloniki; 2020. Online. Available from: <https://Www.Urenio.Org/2020/12/24/Smart-City-Ontology-2-0>
- [6] Liu D, Huang R, Wosinski M. Development of smart cities: Educational perspective. In: Smart Learning in Smart Cities. Lecture Notes in Educational Technology. Singapore: Springer; 2017. DOI: 10.1007/978-981-10-4343-7_1
- [7] Komninos N et al. Smart city ontologies: Improving the effectiveness of smart city applications. Journal of Smart Cities. 2019;**1**(1):31-46
- [8] Thuzar M. Urbanization in Southeast Asia: Developing smart cities for the future. Regional Outlook. 2011;**96**:96-100
- [9] Arroub A et al. A literature review on smart cities: Paradigms, opportunities and open problems. In: 2016 International Conference on Wireless Networks and Mobile Communications (WINCOM). New York City and Piscataway, New Jersey: IEEE; 2016
- [10] Nam T, Pardo TA. Conceptualizing smart city with dimensions of technology, people, and institutions. In: Proceedings of the 12th Annual International Digital Government Research Conference: Digital Government Innovation in Challenging Times. New York: Association for Computing Machinery (ACM); 2011
- [11] Wolff A, Kortuem G, Cavero J. Towards smart city education. In: 2015 Sustainable Internet and ICT for Sustainability (SustainIT); Madrid, Spain. New York City and Piscataway, New Jersey: IEEE; 2015. pp. 1-3. DOI: 10.1109/SustainIT.2015.7101381
- [12] Hollands RG. Will the real smart city please stand up? City: Analysis of urban trend, culture, theory. Policy, Action. 2008;**12**(3):303-320
- [13] Neirotti P et al. Current trends in Smart City initiatives: Some stylised facts. Cities. 2014;**38**:25-36
- [14] Mazza P. Education & Smart Cities: The role of the goals of agenda 2030 for sustainable development of smart cities. International Journal Innovative Studies in Socioly Humanities. 2021;**6**(2):24-31
- [15] Liu D, Huang R, Wosinski M. Contexts of smart learning

- environments. In: Smart Learning in Smart Cities. Lecture Notes in Educational Technology. Singapore: Springer; 2017. DOI: 10.1007/978-981-10-4343-7_2
- [16] Caragliu A, Del Bo C, Nijkamp P. Smart cities in Europe. *Journal of Urban Technology*. 2011;**18**(2):65-82
- [17] Klett F. Plenary talk: Smart cities–infrastructures and technologies for education and human and skills development. In: IEEE-CCD Guadalajara Smart City Launch, Guadalajara Mexico. New York City and Piscataway, New Jersey: IEEE; 2013
- [18] Molnar A. Education in smart cities: Practices and challenges. In: Proceedings of the IADIS International Conference Applied Computing, Held by Università degli Studi di Cagliari Italy in 2019; Utrecht, the Netherlands. 2019
- [19] Boes K, Buhalis D, Inversini A. Smart tourism destinations: Ecosystems for tourism destination competitiveness. *International Journal of Tourism Cities*. 2016;**2**(2):108-124
- [20] Cowley R et al. Ordinary Chinese smart cities: The case of Wuhan. In: Inside Smart Cities Anonymous. UK and USA: Taylor & Francis eBooks; 2018
- [21] Salerno S, Nunziante A, Santoro G. Competences and knowledge: Key-factors in the smart city of the future. *Knowledge Management & E-Learning*. 2014;**6**(4):356
- [22] Iatrellis O et al. Cloud computing and semantic web technologies for ubiquitous management of smart cities-related competences. *Education and Information Technologies*. 2021;**26**:2143-2164
- [23] Winters JV. Why are smart cities growing? Who moves and who stays. *Journal of Regional Science*. 2011;**51**(2):253-270
- [24] Kadar M. Smart learning environment for the development of smart city applications. In: 2016 IEEE 8th International Conference on Intelligent Systems (IS). New York City and Piscataway, New Jersey: IEEE; 2016
- [25] Washburn D et al. Helping CIOs understand “smart city” initiatives. *Growth*. 2009;**17**(2):1-17
- [26] Vadim Z et al. Analysis of smart cities education needs. *Автоматика И Программная Инженерия*. 2019;**4**(30):88-102
- [27] Zhuang R et al. Smart learning environments for a smart city: From the perspective of lifelong and lifewide learning. *Smart Learning Environments*. 2017;**4**:1-21
- [28] Salerno S. Knowledge lifecycle and smart cities learning position paper for DUBAI 2020: Smart city learning. In: 2014 International Conference on Web and Open Access to Learning (ICWOAL). New York City and Piscataway, New Jersey: IEEE; 2014
- [29] Nahhas S. Potentials of semantic internet of things in smart cities: An overview and roadmap. In: 2023 1st International Conference on Advanced Innovations in Smart Cities (ICAISC). New York City and Piscataway, New Jersey: IEEE; 2023
- [30] Wu L et al. A semantic web-based recommendation framework of educational resources in E-learning. *Technology, Knowledge and Learning*. 2020;**25**:811-833
- [31] Jara AJ et al. An analysis of context-aware data models for smart cities: Towards fiware and etsi cim emerging

data model. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. 2017;**42**:43-50

[32] Consoli S et al. A smart city data model based on semantics best practice and principles. In: Proceedings of the 24th International Conference on World Wide Web. New York: Association for Computing Machinery (ACM); 2015

[33] Belizario MG, Berardi RCG. Use of smart and open data in smart cities. In: 25th Americas Conference on Information Systems, AMCIS 2019; 15-17 August 2019; Cancún, Mexico. 2019. Available from: <https://researchr.org/publication/amcis-2019>

[34] Hammad R, Ludlow D. Towards a smart learning environment for smart city governance. In: Proceedings of the 9th International Conference on Utility and Cloud Computing. New York: Association for Computing Machinery (ACM); 2016

[35] Molnar A. Smart cities education: An insight into existing drawbacks. *Telematics and Informatics*. 2021;**57**:101509

[36] Wieringa RJ. Design Science Methodology for Information Systems and Software Engineering. Princeton, New Jersey, USA: Springer; 2014

[37] Pattuelli MC, Provo A, Thorsen H. Ontology building for linked open data: A pragmatic perspective. *Journal of Library Metadata*. 2015;**15**(3-4):265-294

[38] Poveda Villalón M, Suárez-Figueroa MC, Gómez-Pérez A. The landscape of ontology reuse in linked data. In: *Ontology Engineering in a Data-Driven World (OEDW 2012)* in Galway, Irlanda by Facultad de Informática

(UPM) in October 2012. 2012. Available from: <https://oa.upm.es/14385/>

[39] Simperl E. Reusing ontologies on the semantic web: A feasibility study. *Data & Knowledge Engineering*. 2009;**68**(10):905-925

[40] Zhong G, Zhang X. A building of the current intelligent learning environment model. *Computer Science*. 2006;**1**:170-171

[41] Renzel D et al. Tracing self-regulated learning in responsive open learning environments. In: *Advances in Web-Based Learning--ICWL 2015: 14th International Conference, Guangzhou, China, November 5-8, 2015, Proceedings 14*. Princeton, New Jersey, USA: Springer; 2015

[42] Spector JM. Conceptualizing the emerging field of smart learning environments. *Smart Learning Environments*. 2014;**1**:1-10

[43] Popleteev A et al. Touch by touch: Promoting cultural awareness with multitouch gaming. In: *2013 International Conference on Smart Communications in Network Technologies (SaCoNeT)*. New York City and Piscataway, New Jersey: IEEE; 2013

[44] Tlili A et al. Automatic modeling learner's personality using learning analytics approach in an intelligent moodle learning platform. *Interactive Learning Environments*. 2023;**31**(5):2529-2543

[45] Zhu ZT, Bin H. Smart education: A new paradigm in educational technology. *Telecommunication Education*. 2012;**12**:3-15

[46] Mikroyannidis A. A semantic framework for cloud learning environments. In: *Cloud Computing for*

Teaching and Learning: Strategies for Design and Implementation Anonymous. Hershey, Pennsylvania New York, New York Beijing, China: IGI Global; 2012

[47] Iatrellis O et al. An intelligent expert system for academic advising utilizing fuzzy logic and semantic web technologies for smart cities education. *Journal of Computers in Education*. 2023;**10**(2):293-323

[48] Iatrellis O, Kameas A, Fitsilis P. Academic advising systems: A systematic literature review of empirical evidence. *Education Sciences*. 2017;**7**(4):90

[49] Nikolov R et al. Learning in a smart city environment. *Journal of Communication and Computer*. 2016;**13**(7):338-350

[50] Nahhas S et al. Leveraging linked data to propel competency-based education based on labour skills. In: 2019 2nd International Conference on Computer Applications & Information Security (ICCAIS). New York City and Piscataway, New Jersey: IEEE; 2019

[51] Nahhas S et al. Bridging education and labor skills by a novel competency-based course linked-data model. *IEEE Access*. 2019;**7**:119087-119098

[52] Nahhas S et al. Added values of linked data in education: A survey and roadmap. *Computers*. 2018;**7**(3):45

[53] Koper R. Conditions for effective smart learning environments. *Smart Learning Environments*. 2014;**1**:1-17

[54] Boulanger D et al. Smart learning analytics. In: *Emerging Issues in Smart Learning*. Princeton, New Jersey, USA: Springer; 2015

[55] Li BP, Kong SC, Chen G. A study on the development of the smart classroom

scale. In: *Emerging Issues in Smart Learning*. Princeton, New Jersey, USA: Springer; 2015

[56] Hwang G. Definition, framework and research issues of smart learning environments-a context-aware ubiquitous learning perspective. *Smart Learning Environments*. 2014;**1**:1-14

[57] Jones V. Ubiquitous learning environment: An adaptive teaching system using ubiquitous technology. In: *Beyond the Comfort Zone: Proceedings of the 21st ACILITE Conference*. Australia: Griffith University; 2004

[58] Yang SJ, Okamoto T, Tseng S. Context-aware and ubiquitous learning (guest editorial). *Journal of Educational Technology & Society*. 2008;**11**(2):1

[59] Nahhas S et al. Linked data approach to mutually enrich traditional education resources with global open education. In: 2018 1st International Conference on Computer Applications & Information Security (ICCAIS). New York City and Piscataway, New Jersey: IEEE; 2018

[60] Klett F, Wang M. Smart cities of the future: Creating tomorrow's education toward effective skills and career development today. *Knowledge Management & E-Learning: An International Journal*. 2014;**6**(4):344-355

[61] Perini S et al. An ontology-based model for training evaluation and skill classification in an industry 4.0 environment. In: *Advances in Production Management Systems. The Path to Intelligent, Collaborative and Sustainable Manufacturing: IFIP WG 5.7 International Conference, APMS 2017, Hamburg, Germany, September 3-7, 2017, Proceedings, Part I*. Princeton, New Jersey, USA: Springer; 2017

[62] Gu T et al. An ontology-based context model in intelligent environments. arXiv Preprint arXiv:2003.05055. 2020. Available from: <https://arxiv.org/abs/2003.05055>

[63] Slot and Esther. Multi-, Inter-, and Transdisciplinarity; What is What? Available from: <https://www.uu.nl/en/education/educational-development-training/knowledge-dossiers/interdisciplinary-education-and-cel/multi-inter-and-transdisciplinarity-what-is-what>

[64] Compton M et al. The SSN ontology of the W3C semantic sensor network incubator group. *Journal of Web Semantics*. 2012;17:25-32

Section 2

Systems, Applications, and Regional Pathways

Improving Energy Efficiency and Sustainability in Smart Cities

Sudaff Mohammed, Duha A. Jebur and Zahraa M. Ibrahim

Abstract

Amid growing global concerns over energy consumption and environmental degradation, passive architectural design is significantly transforming through its convergence with emerging technologies. The integration of Artificial Intelligence (AI), Machine Learning (ML), and the Internet of Things (IoT) has allowed passive design to evolve into intelligent, adaptive systems capable of optimizing building performance in real time. This innovative synergy redefines conventional architectural strategies by embedding smart functionalities within materials, façades, and environmental systems. Predictive modeling enhances the configuration of façades and fenestration, allowing them to respond dynamically to climate conditions. AI-enhanced innovative materials facilitate thermal responsiveness, adjusting properties such as insulation and shading in reaction to environmental inputs. Meanwhile, IoT-enabled environmental control systems continuously gather data on occupancy and climatic variables to regulate indoor conditions efficiently. Together, these technologies foster the development of self-regulating, energy-efficient buildings that maintain occupant comfort without compromising design flexibility or architectural integrity. The success of these systems depends on real-time data analysis, sensor-driven customization, and algorithmic learning, which collectively support responsive building environments. Strategic changes are necessary across financial, regulatory, and cultural domains to harness their potential fully. Encouraging interdisciplinary collaboration and innovation is essential for scaling these technologies and addressing implementation challenges. AI-integrated passive design presents a forward-looking architectural paradigm that aligns ecological responsibility with technological advancement while supporting the transition toward sustainable, intelligent built environments.

Keywords: AI-integrated passive design, energy efficiency, smart cities, predictive modeling, sustainability

1. Introduction

Urbanization is moving at an unmatched speed. More than half of the world's population presently lives in cities, which is expected to increase dramatically in the following decades [1]. Energy use, environmental damage, and resource shortage are all significant concerns this population change presents. Cities become the main engines of worldwide energy demand and greenhouse gas emissions as they get more complicated and denser. This reality emphasizes the need to rethink metropolitan

areas to be more energy-efficient, robust, and environmentally friendly. The “smart city” idea has developed into a multifaceted framework tackling these issues [2]. A smart city, at its heart, uses digital technologies, including artificial intelligence (AI), machine learning (ML), and the Internet of Things (IoT), to maximize infrastructure, services, and governance systems. By increasing efficiency, lowering environmental impact, and supporting sustainable economic development, this technological integration seeks to improve urban living. The physical environment, especially how buildings are planned, run, and maintained, is among the principal fields where innovative technologies show great promise. Nearly 40% of world energy use is attributed to buildings, most caused by heating, cooling, lighting, and ventilation [3]. Traditionally, ways to increase building efficiency have mostly emphasized active systems using more energy to provide comfort. However, a change is underway: intelligent technologies are reinterpreting passive design tactics, which depend on natural processes, as passive design approaches. The combination of passive design and innovative systems offers a creative solution to lower energy reliance and enhance interior environmental quality. Artificial intelligence and IoT technology are included in the design and management of structures, allowing for autonomous ecological control, predictive modeling, and real-time data collection [4]. These features let buildings evolve from static physical objects into dynamic, adaptive systems that react smartly to human and environmental inputs. Buildings, for example, can now monitor real-time occupancy patterns, “learn” from past weather data, and change lighting or ventilation to lower energy waste and improve user comfort. Furthermore, smart materials that actively support energy saving have been made possible by developments in material science mixed with artificial intelligence analysis. Among these are insulation changing thermal characteristics in reaction to temperature variations, electrochromic glass changing to light levels, and phase-change materials controlling heat flow. Such materials produce building envelopes competent of self-adjustment when embedded with sensors and controlled by intelligent algorithms, hence improving the efficiency of passive design. IoT-enabled control systems that centralize and automate internal climate management, lighting, air quality, and energy use further improve smart buildings. These systems constantly optimize building operations using machine learning models applied to real-time environmental conditions captured by sensors. This strategy guarantees constant passenger comfort and lowers environmental effects and running expenses. Though they hold great hope, putting smart systems in sustainable urban areas presents some difficulties. Often, high initial costs, difficulty integrating various technologies, data protection issues, and absence of legal frameworks impede broad adoption [5]. Moreover, differences in access to new technologies between rich and poor countries create doubts about fairness and inclusiveness in the move to smarter, more sustainable cities. This chapter will underline how crucial interdisciplinary cooperation is in tackling these difficulties. Architects, engineers, data scientists, urban planners, and legislators must work together to develop solutions that fit local settings, cultural values, and long-term sustainability objectives. Accelerating the adoption of smart and sustainable design ideas depends on policy innovation, public-private collaborations, and education. By investigating how new technologies could change energy use in buildings and cities, this chapter will add to the larger conversation on urban sustainability. It emphasizes the changing part of artificial intelligence, machine learning, and IoT in maximizing building performance, reducing environmental effects, and improving urban livability. Viewed in this way, cities are smart ecosystems competent of learning, adapting, and developing in reaction to human and environmental requirements rather

than only physical places. Smart cities that combine passive design ideas with smart technologies could offer the most promising blueprint for a greener and more resilient urban future as global climate goals get more ambitious and the need for sustainability increases.

2. The application of powered predictive modeling to assess the performance of passive infrastructure

Integrating artificial intelligence (AI) and machine learning (ML) into sustainable architecture design has fundamentally transformed the performance optimization of passive buildings [6]. According to Elwy et al., AI applications in building performance prediction are vital in addressing computational inefficiencies and reducing the costs of tackling more complex optimization challenges for environmental sustainability. While machine learning-based surrogate models (SMs) have been widely utilized in advanced optimization research across various fields, their relevance and reliability in sustainable and low-energy architecture design are currently under thorough examination. These AI-driven models enhance accuracy and efficiency in refining passive design strategies by serving as a strong alternative to traditional computational methods [7]. Unlike conventional structures, passive buildings utilize an energy-efficient approach to reduce their dependence on active heating, ventilation, and air conditioning (HVAC) systems [8]. AI and ML are crucial to energy management tactics because they analyze historical and real-time environmental data to improve heating, cooling, and daylighting solutions. Overreliance on fossil fuels has led to rising energy costs, greenhouse gas (GHG) emissions, and increasing global temperatures, according to Ogundiran [9]. These urgent concerns highlight the need to switch to alternate energy sources and take prompt action to reduce energy usage and improve energy efficiency. Approximately 70% of building energy use comes from HVAC systems. Thus, any energy-saving approach must balance efficiency increases with indoor environmental quality. Predictive modeling is essential for simulating and assessing facade configurations and fenestration layouts before installation. These guarantee buildings maximize energy efficiency and comfort [9, 10]. Furthermore, dynamically adapting to changing environmental conditions, including intelligent materials such as phase-changing materials (PCMs) in AI-powered systems, improves the efficiency of passive design techniques. This chapter focuses on three main areas: predictive modeling for facade and fenestration optimization, artificial intelligence-driven smart materials integration, and real-time data analytics for sustainable temperature control. The purpose of this chapter is to assess, from a critical standpoint, how artificial intelligence and machine learning could help to design passive buildings.

2.1 The use of predictive modeling for the optimization of facades and fenestration patterns

2.1.1 Artificial intelligence-driven facade configurations

Heat gain, daylight penetration, and ventilation are all factors that directly influence a structure's energy efficiency, and building facades play a significant role in managing these factors [11]. The design of building facades has conventionally depended on iterative and heuristic approaches, which, although prevalent, are

frequently laborious and may not produce optimal performance results. The emergence of artificial intelligence (AI)-based predictive modeling has revolutionized this process by fostering more efficient, data-informed decision-making. As Shan et al. noted, facade design significantly influences a building's energy efficiency and environmental footprint, especially in high-performance architecture. Nevertheless, optimizing facade parameters poses a complex challenge, necessitating the reconciliation of multiple, often conflicting, design variables to achieve varied performance goals. AI-driven predictive modeling mitigates this complexity by systematically analyzing extensive datasets, identifying optimal configurations, and enabling adaptive, high-performance facade solutions that improve energy efficiency and occupant comfort [12]. This modeling method analyzes enormous datasets that contain historical and real-time climate factors to develop the most effective facade designs ever. The modeling of different facade scenarios is enabled by sophisticated generative design algorithms based on artificial intelligence [13]. These algorithms analyze sun path trajectories, wind patterns, and seasonal heat variations. These computational models enable architects to balance esthetics with energy efficiency. Parametric modeling tools like Grasshopper and machine learning algorithms can evaluate façade materials and combinations for thermal and daylighting performance before installation. Data-driven decision-making guarantees adherence to sustainable design standards.

2.1.2 Virtual simulation of fenestration layouts

Maximizing natural light and enhancing passive ventilation rely strategically on the configuration of fenestration. Hardi K. Abdullah argue that natural ventilation (NV) is the most favorable cost-effective method to introduce fresh air into interior spaces, significantly improving indoor environmental quality [14]. Architects can practically ensure that daylight consumption is maximized while simultaneously minimizing any undesired heat gains or losses by analyzing several fenestration layouts using technologies driven by artificial intelligence incorporated with machine learning models trained on massive datasets to address real-time environmental variables. This facilitates the prediction of the most effective fenestration solutions. Examining airflow distribution is further made more manageable by simulations using computational fluid dynamics (CFD), which ultimately increases the effectiveness of passive ventilation practices [15]. This AI-powered technology reduces design uncertainties, enabling architects to construct data-informed fenestration layouts that reduce energy consumption without compromising occupants' comfort.

2.1.3 Automated optimization of thermal performance

Integrating artificial intelligence (AI) and machine learning (ML) in passive building design extends beyond optimizing static architectural features to encompass dynamic temperature control. Supported by a growing body of recent research, Villano et al. emphasize that artificial intelligence is a powerful tool for modeling and enhancing building energy performance [16]. Intelligent shading systems, which are integrated with sensors controlled by artificial intelligence, dynamically regulate fenestration features to maintain thermal balance inside the building. Real-time artificial intelligence algorithms manage shading devices depending on sun exposure and occupant activity. This prevents excessive solar heat uptake during summer and makes it easier for passive solar heating to occur during winter. This clever

modification lessens the reliance on mechanical heating, ventilation, and air conditioning (HVAC) systems, promoting sustainability and maximizing energy efficiency in passive structures. An academic review of AI-driven predictive modeling employed in building design is shown in the following table. Regarding façade optimization, fenestration analysis, and thermal performance enhancement, it discusses the essential ideas, technologies, advantages, possibilities, and associated difficulties. An improvement in energy efficiency and sustainability in architectural practices may be achieved by integrating artificial intelligence and machine learning, which enables data-driven decision-making.

2.2 The integration of artificial intelligence-driven smart materials

2.2.1 Phase-changing materials (PCMs) for thermal regulation are discussed in section

Phase-changing materials, also known as PCMs, are unique compounds that can store and release thermal energy, allowing them to maintain temperatures inside buildings [17] successfully. PCM deployment may be optimized using AI-enhanced predictive modeling thanks to the analysis of past temperature changes and environmental circumstances. This allows for the determination of ideal use patterns. Buildings can dynamically control heat absorption and dissipation depending on seasonal fluctuations when artificial intelligence (AI) systems are integrated with PCM technology [18]. Artificial intelligence algorithms are used to fine-tune PCM activation thresholds to ensure that these materials retain excess heat during peak thermal times and release it when temperatures decrease. This is accomplished using predictive meteorological modeling. This strategy reduces the need for artificial heating and cooling systems, helps to improve the comfort of occupants, and limits the amount of temperature changes that occur inside the building.

2.2.2 Smart glazing technologies guided by artificial intelligence

Both electrochromic and thermochromic glass are innovative glazing technologies that offer adaptive control over the amount of light transmitted and the amount of thermal insulation provided [19]. Predictive algorithms powered by artificial intelligence provide predictions about the best tinting levels depending on the current and expected weather conditions to improve these technologies. Machine learning algorithms use massive datasets to assess weather patterns and occupant preferences. This method enables automatic modifications to be made to the qualities of glazing. During peak daylight hours, bright windows powered by artificial intelligence will dynamically change their transparency to prevent glare and minimize cooling loads [20]. This will result in an improvement in both visual comfort and energy efficiency. This clever adaptation of passive daylighting solutions highlights the potential for artificial intelligence to bring about revolutionary change in sustainable building.

2.2.3 Self-adapting insulating materials

Self-adaptive insulating materials with dynamical thermal resistance have been made possible by introducing artificial intelligence (AI), which assisted in developing these materials [21]. AI-powered materials respond to variable ambient circumstances to adjust their performance, benefiting from AI-powered actuators that are embedded into them. These actuators minimize the need for human intervention by regulating

insulation thickness depending on real-time climatic data, leading to maximized energy savings [22]. Integrated artificial intelligence allows passive buildings to achieve higher insulation performance, which guarantees appropriate thermal conditions regardless of variations in the temperature of the surrounding environment. This self-regulating system considerably improves energy efficiency, lowering the level of energy consumption during operations while maintaining the comfort of the occupants.

2.3 The application of real-time data analytics to the regulation of sustainable climate

2.3.1 Artificial intelligence-enabled climate prediction models

Artificial intelligence-powered climate prediction models use several meteorological datasets to generate reliable temperature, humidity, and solar radiation projections [23]. These predictive powers allow proactive design changes meant to improve the performance of passive structures. AI-driven forecasting models, for example, can account for severe storms and modify passive design elements. Artificial intelligence algorithms may predict and optimize natural ventilation systems to improve the thermal comfort of indoor environments approaching a heatwave. On the other hand, AI-driven systems can adjust passive heating systems in colder months, therefore removing the energy-intensive heating solutions required to keep ideal interior temperatures [24].

2.3.2 Changes in the passive heating and cooling systems through dynamic adjustment

Automation systems that are empowered with artificial intelligence make it possible to make real-time adjustments to how passive heating and cooling devices work in response to shifting ambient circumstances [25]. To successfully adjust passive heat management systems, machine learning algorithms continually monitor occupancy patterns, interior air quality, and external environmental factors. For example, artificial intelligence-driven thermal mass activation procedures allow buildings to collect and store heat during the day and then gradually release it at night to compensate for the need for cooling. Ventilation systems powered by artificial intelligence regulate airflow rates dynamically, ensuring that natural cooling is delivered with little energy expenditure. The sustainability of passive architectural designs is considerably improved by these climate control technologies that adaptively adjust themselves [26].

2.3.3 Adaptive comfort strategies that are focused on the occupant

Passive construction techniques powered by artificial intelligence focus on occupant-centric adaptive comfort solutions and maximizing energy efficiency [27]. Artificial intelligence models analyze occupant behavior, preferences, and environmental variables to tailor indoor settings dynamically. Sensors embedded in a building capture data about occupancy patterns in real time, which enables automatic modifications to the settings for daylighting, ventilation, and thermal management to improve user comfort. To provide one example, artificial intelligence systems can identify the desired temperature conditions of inhabitants and then change passive heating tactics accordingly [28]. Similarly, artificial intelligence-driven daylighting controls adjust brightness levels in response to human preferences, eliminating glare while supplying sufficient natural illumination. Both energy efficiency and

the quality of the interior environment are improved by artificial intelligence using occupant-centric adaptive comfort solutions. In passive building design, artificial intelligence and machine learning alter the landscape via predictive modeling, innovative materials, and real-time data analytics. Facade and fenestration optimization driven by artificial intelligence can improve energy efficiency by developing design configurations guided by data. Thermal regulation and daylighting methods can be enhanced by utilizing intelligent materials powered by artificial intelligence, such as PCMs and dynamic glazing. Real-time data analytics provided by artificial intelligence also enable passive buildings to have self-adaptable temperature control systems, ensuring occupants' highest possible comfort level while reducing energy usage [29]. Additionally, as artificial intelligence and machine learning technologies advance, their function in passive architecture will grow more complex. Improved artificial intelligence-driven adaptive control systems and expanded integration of these systems with new sustainable materials should be the primary focus of research in the future. The built environment can make remarkable breakthroughs in energy-efficient design by utilizing predictive modeling powered by artificial intelligence. This will help to develop a future that is both robust and sustainable.

3. IoT-enabled passive systems and smart sensors: An approach for improved sustainability and efficiency

3.1 Expanding home efficiency via IoT integration

As a transformative force in modern technology, the Internet of Things (IoT) fosters seamless integration between smart devices and digital infrastructure. According to Uzoka, telecoms have become vital as IoT evolves, significantly boosting connectivity and expanding its applications [30]. A breakthrough in modern home design, IoT-enabled passive systems significantly enhance energy efficiency, resource utilization, and sustainability in living environments because of their passive nature. Automating natural ventilation systems is a key IoT application in this area, essential for reducing energy consumption. Fakhabi et al. notes that the global energy crisis has remained a significant challenge for decades, threatening environmental sustainability and economic stability. Despite government initiatives to improve living standards and social welfare, increasing energy intensity has considerably elevated energy consumption, undermining these efforts. Researchers have systematically analyzed historical energy consumption data over the years to develop and implement innovative technological solutions that maximize energy efficiency and mitigate the negative impacts of excessive energy use [31]. Adaptive ventilation solutions can use intelligent sensors to monitor humidity, temperature fluctuations, and air quality [32]. These methods dynamically control airflow, reducing reliance on mechanical ventilation systems and lowering energy consumption. Intelligent building envelopes respond to external environmental conditions using adaptable facades equipped with motorized louvers and electrochromic glass. These technologies reduce thermal loads while maintaining optimal indoor comfort levels, contributing to energy conservation [33]. Optimizing lighting systems is another key aspect of IoT-driven home efficiency. Motion detection, daylight harvesting, and predictive algorithms are incorporated into advanced lighting solutions, helping to adjust illumination levels based on occupancy and the availability of natural light. This not only saves energy but also enhances visual comfort. Smart blinds and electrochromic windows complement

automated shading systems that manage solar radiation penetration. These strategies contribute to energy savings and tenant well-being by reducing reliance on mechanical cooling and artificial lighting. Real-time monitoring and control of residential energy use heavily depend on IoT-driven energy management systems. These systems employ advanced analytics to evaluate consumption trends and optimize energy distribution, for example, by shifting power usage to non-peak hours. Smart thermostats improve efficiency by learning user preferences and autonomously adjusting climate control settings, minimizing energy waste [34]. Furthermore, IoT-enabled home appliances like washing machines and energy-efficient refrigerators utilize real-time data processing to enhance operational performance and reduce overall energy usage.

3.2 Leveraging smart technologies to improve security and comfort

3.2.1 Reviews intelligent temperature control and adaptive environmental management

Using Internet of Things (IoT) linked technologies in homes has significantly improved environmental adaptability and temperature control. Intelligent heating, ventilation, and air conditioning (HVAC) systems employ an extensive network of sensors to continuously monitor key variables like temperature, humidity, and air quality. Using artificial intelligence (AI)-driven learning algorithms, these systems can autonomously assess user behavior patterns and preferences. This capacity helps the systems to make exactly anticipated changes [35]. By using these predictive powers, thermal comfort is enhanced, and the energy economy is raised. Moreover, installing smart thermostats allows one to synchronize with occupancy patterns and weather forecasts perfectly. This lets the anticipatory environmental control line up with changes in the outside temperature. Another significant development in adaptive ecological management is the application of dynamic shading technologies, including automated shading systems and electrochromic smart glass. Using real-time environmental data, these technologies dynamically modify light and temperature penetration, thus reducing dependency on artificial climate control systems, lowering glare, and enabling sustainable energy use [36].

3.2.2 Highly developed systems of home security and possible hazard detection

Internet of Things (IoT)-enabled security systems, combined with artificial intelligence (AI), automation, and real-time data analytics, have reinterpreted modern household safety paradigms [37]. Smart surveillance systems can help to simplify proactive threat identification and risk assessment. These systems comprise motion-sensitive sensors, facial recognition algorithms driven by artificial intelligence, and high-resolution cameras. These sophisticated devices continuously evaluate environmental cues and separate them between regular activities and suspected security breaches. This is unlike conventional security systems, which largely depend on reactive countermeasures. Automated alarm systems enable quick notifications to emergency response teams and citizens, accelerating the intervention processes [38]. Furthermore, using smart locks and biometric access control systems helps improve security by using dynamic access permission. Homeowners may instantly give or revoke entrance credentials using encrypted smartphone apps with remote access control. Moreover, integrating connected security systems improves situational awareness through communication between many devices, enabling the autonomous

coordination of security reactions. Integrating several technologies significantly improves home security systems by lowering response latency and boosting perimeter defense mechanisms [39].

3.2.3 Combining reaction to emergencies with protection against fire

Apart from its function in avoiding intrusions, Internet of Things-based technologies have significantly enhanced fire safety and emergency response capacities in residential environments [40]. Intelligent smoke and gas leak detection systems in networked smart home ecosystems provide real-time hazard monitoring. These devices analyze the surroundings constantly. These devices instantly notify homes and emergency response teams when they find anomalies, therefore lowering the possibility of future issues before they get more serious. Modern home automation systems integration makes automated risk reduction strategies feasible [41]. Among these tactics are turning off HVAC systems to slow down the development of smoke, unlocking exit routes for a faster evacuation, and turning on emergency lights to provide a better view. Furthermore, these fire safety systems operate inside a centralized Internet of Things architecture, ensuring smooth interaction with many other smart home appliances. Through predictive analytics and autonomous response systems, Internet of Things (IoT)-driven safety systems help create a stronger and more responsive household environment. This supports the success of occupant protection and disaster avoidance [42].

Table 1 summarizes the main features, difficulties, and prospects related to IoT-enabled smart home technologies. It notes developments in smart temperature control, security systems, and emergency response integration. These developments improve fire safety, security, and energy efficiency; yet issues including cybersecurity threats, expensive expenses, and interoperability still exist. Still, the possible advantages of sustainability, improved safety, and quick emergency response are great.

3.3 Sustainable resource optimizing and economical maintenance

IoT-enabled passive systems provide significant benefits, including their ability to facilitate predictive maintenance and enhance long-term resource management [43]. This results in reduced operating costs and improved sustainability through lower running expenses. IoT-based monitoring systems continuously evaluate structural components and household appliances, revolutionizing predictive maintenance [44]. These systems generate proactive maintenance alerts and identify issues such as mechanical wear or inefficiencies in energy use. This data-driven approach significantly decreases maintenance costs, extends equipment lifespan, and minimizes unexpected failures. Another area where IoT integration proves beneficial is in water resource management. By utilizing real-time soil moisture monitoring and meteorological data, intelligent irrigation systems ensure accurate water distribution and prevent overuse, supporting ecological balance [45]. Similarly, IoT-enabled leak detection devices identify plumbing problems early, reducing water waste and preventing structural damage associated with leakage. The importance of IoT in sustainable development is further underscored by its role in urban ecological solutions like vertical gardens and green rooftops. Embedded sensors in these systems monitor soil conditions, plant hydration levels, and ambient humidity, ensuring proper maintenance of green infrastructure [46]. Such advancements improve thermal comfort by providing natural insulation, reducing heat absorption, and reducing reliance

Title	Key concepts	Technologies used	Benefits	Opportunities	Challenges
AI-driven optimization of facade designs	AI-driven predictive modeling enhances façade designs by examining climate data, solar paths, and wind patterns.	Generative design algorithms, parametric modeling (Grasshopper), and machine learning.	It enhances energy efficiency, improves decision-making, and balances aesthetics with functionality.	Enhanced energy efficiency, greater design flexibility, and data-driven architectural choices.	High computational demands, the requirement for large datasets, and the complexity of AI model training.
Computational analysis of window layouts	AI-driven simulations optimize window placement to maximize daylight and passive ventilation while reducing heat gain or loss.	Machine learning models and computational fluid dynamics (CFD) simulations.	Optimizes daylight usage, reduces undesirable thermal effects, and enhances passive ventilation.	Improved occupant comfort, precise control of daylight and ventilation, and predictive modeling for future designs.	Reliance on precise environmental data and the potential for high initial costs associated with AI implementation.
Machine learning-enhanced thermal performance	AI-controlled shading systems actively manage thermal conditions to lessen HVAC reliance and promote sustainability.	AI-controlled sensors, real-time AI algorithms, and dynamic shading systems.	Decreases dependence on mechanical HVAC systems, enhances thermal comfort, and supports sustainability.	Smart building integration, adaptive thermal regulation, and reduced operational energy costs.	Integration with current building systems, the expense of AI-driven shading solutions, and maintenance difficulty.

Table 1.
AI-driven predictive modeling in building design.

on traditional cooling systems. Beyond individual homes, IoT devices extend into smart city infrastructure, where interconnected urban ecosystems employ real-time data analytics to enhance operational efficiency [47]. IoT sensors enable intelligent transportation systems to optimize traffic flow, reduce congestion, and streamline public transit networks. Likewise, innovative waste management systems utilize IoT-enabled monitoring to improve recycling practices and optimize collection routes, lowering municipal operating costs and environmental impacts. IoT-enabled smart sensors and passive systems significantly advance urban and household sustainability [48]. IoT contributes to a more resilient, affordable, and ecologically responsible built environment by improving energy efficiency, optimizing environmental management, ensuring security, and supporting predictive maintenance. IoT integration will become essential as technological innovation progresses, shaping intelligent living environments and accelerating the global transition toward a more connected and sustainable future. This graph shows that IoT-enabled passive systems help with predictive maintenance, resource management, and sustainability. Important uses comprise smart monitoring, water management, urban solutions, and smart cities. By combining these technologies, IoT improves long-term environmental sustainability in urban and home environments, lowering costs and increasing efficiency.

4. Passive design integrated by AI: Prospects and policy challenges

A fundamental approach to sustainable architecture, passive design, which optimally utilizes natural environmental conditions, is gaining significance. Passive design solutions are essential for decreasing energy consumption and enhancing occupant comfort by lowering reliance on mechanical heating, cooling, and artificial lighting systems. Passive design maximizes building efficiency and promotes long-term environmental sustainability by utilizing natural resources, including solar radiation, natural ventilation, and daylight. Omer underscores that environmental degradation and climate change constitute the most critical global concerns, necessitating an immediate reduction in energy demand [49]. Employing passive and low-energy design strategies in the built environment provides a pragmatic and efficient means to attain thermal comfort while markedly reducing carbon emissions and resource depletion. This method corresponds with extensive global initiatives aimed at sustainable development and the shift to energy-efficient construction techniques, emphasizing the necessity of incorporating environmental factors into architectural and urban design methodologies. Incorporating artificial intelligence (AI) into passive design strategies presents a transformative opportunity to improve adaptability and efficiency. AI-driven solutions have arisen as potent instruments to enhance building performance through predictive modeling, data-informed recommendations for real-time design alterations, and simulations of intricate environmental variables. These features considerably improve the efficacy of passive design strategies by facilitating ongoing optimization and adaptive responses to fluctuating conditions. Utilizing machine learning algorithms and sophisticated analytics, AI can forecast energy requirements, enhance HVAC system efficiency, and regulate lighting and shading systems, so promoting superior energy efficiency and occupant comfort. Ahmed, Ijaz, et al. assert that the increasing imperative to diminish carbon emissions and the worldwide transition to intelligent, energy-efficient structures are hastening the advancement and implementation of advanced control systems. Their study provides a thorough assessment of modern control mechanisms specifically

developed to facilitate the dynamic management of building energy performance [50]. The use of AI-driven controls enhances passive design principles and transforms buildings into responsive, intelligent systems that can address modern sustainability objectives and future energy issues. However, integrating artificial intelligence into passive design raises several legal and policy challenges. Existing legal frameworks may be inadequate to govern AI-assisted decision-making in the built environment. Data governance, algorithmic transparency, ethical considerations, and equitable access to AI-driven solutions must be addressed to ensure responsible implementation. Moreover, disparities in technological access between affluent and developing regions may impede the adoption of sustainable design. It is essential to explore the potential of AI-integrated passive design, its benefits, and policy challenges.

4.1 Policy challenges to passive design integrated with AI

4.1.1 High starting expenses and limited spectrum of financial concerns

The economic viability of passive house construction with artificial integration is still of great concern [51]. The significant initial cost required for the development of AI-integrated passive buildings poses considerable financial difficulties for developers and homeowners. The issues are intensified by the substantial expenses associated with powerful artificial intelligence technology, intricate sensors, and specialized imported materials necessary for optimal building performance. Without substantial financial incentives, including government subsidies, low-interest loans, or tax deductions, the propensity of private homeowners and commercial developers to participate in these creative, capital-intensive projects is constrained. Moreover, the extensive economic environment is exacerbated by the reluctance of financial institutions, such as banks and investors, to completely acknowledge and assess the long-term economic advantages of AI-driven passive design. This uncertainty mostly arises from the challenges associated with precisely predicting energy savings, maintenance reductions, and property value appreciation over prolonged durations. The absence of defined valuation models for sustainable and AI-enhanced building technologies further inhibits institutional backing. The financial viability of such initiatives frequently depends on public policy measures and the establishment of precise metrics for assessing their long-term economic and environmental benefits [52]. Stakeholders find it challenging to get financing, as conventional valuation methods usually overlook these facilities' operating efficiency and energy savings [53]. If more open cost-benefit assessments over the long run and more substantial financial arrangements are not adopted, AI-integrated passive homes will remain financially unattainable for many people.

4.1.2 Opposition to change within social and cultural settings

Financial obstacles, in conjunction with societal and cultural issues, substantially hinder the extensive use of artificial intelligence-driven passive design in the building industry [54]. Substantial initial investment expenditures, together with doubts about long-term financial benefits, deter developers and households from adopting these technologies. Additionally, societal concerns around data privacy, technological dependability, and the possible obsolescence of conventional design methodologies foster skepticism toward the incorporation of AI in building design and operation. Cultural variables significantly impact adoption, as differences in local

construction traditions, user preferences, and technical literacy levels are influential [55]. In specific areas, there is opposition to departing from traditional construction techniques and dependence on automated technologies, arising from a preference for human oversight and familiarity. The absence of focused educational activities and public awareness campaigns obstructs the transmission of information about the environmental and economic advantages of AI-enhanced passive buildings. Confronting these financial, societal, and cultural challenges necessitates collaborative initiatives from policymakers, financial institutions, and industry stakeholders to establish supportive frameworks, incentive structures, and public outreach strategies that foster trust, comprehension, and investment in AI-driven passive design [56]. **Figure 1** delineates significant obstacles impeding the use of AI-driven passive design within the construction sector. Financial, societal, and cultural barriers contribute to widespread resistance to change. Addressing these difficulties necessitates cooperation among politicians, financial institutions, and businesses via supportive frameworks, incentives, and public awareness activities **Figure 2**.

Figure 2 illustrates key barriers hindering the adoption of AI-driven passive design in the building industry. Financial, societal, and cultural obstacles feed into general opposition to change. Overcoming these challenges requires collaboration between policymakers, financial institutions, and industry through supportive frameworks, incentives, and public outreach initiatives [57].

Many people employed in the construction industry and consumers believe that artificial intelligence-based solutions are either too complex or unreliable; hence, they choose conventional building techniques. This mistrust results from a general dislike of change, especially when it involves technology the person finds strange. Regarding adoption rates, public opinion has quite a significant influence. The fact that many people connect artificial intelligence with automation and job loss fuels the existing resistance in the building industry [58]. Thus, to show artificial intelligence's valuable advantages to sustainable design, it is necessary to run concentrated public awareness campaigns, educational initiatives, and proactive contact with industry professionals

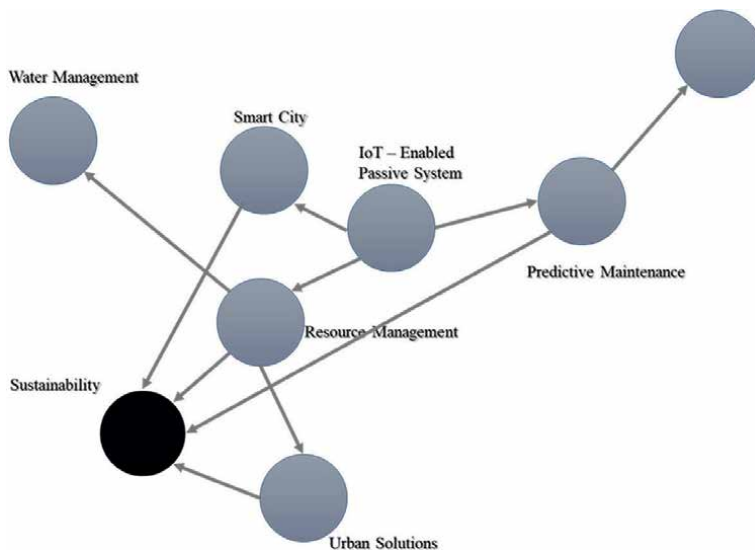


Figure 1.
The function of passive systems supported by IoT in smart cities and sustainability.

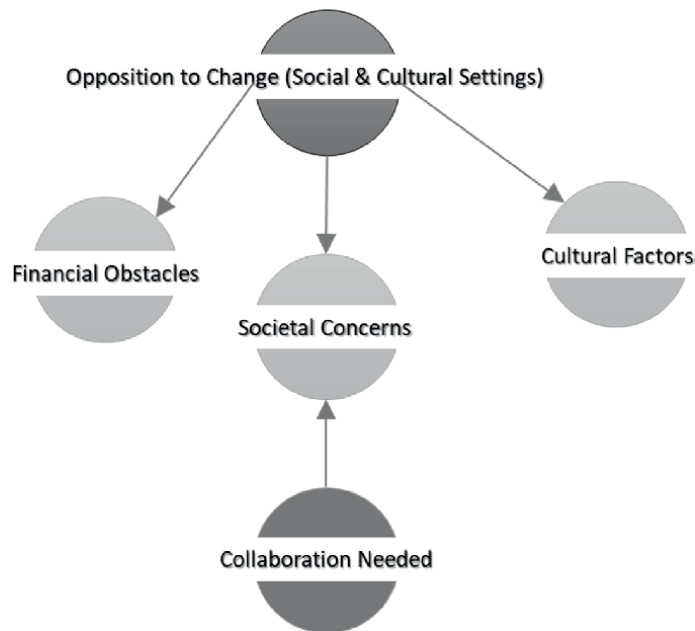


Figure 2.
Barriers and collaborative solutions for AI-driven passive design adoption.

to overcome these challenges. If artificial intelligence (AI) is not embraced universally and with confidence, its inclusion into passive design will find it challenging to gather traction among the public. **Table 3** highlights the social and economic constraints and primary policy challenges in AI-integrated passive design. Adoption is hindered by high initial costs, a lack of financial incentives, and difficulties securing capital. Additionally, general adoption in the building sector is further slowed by opposition to artificial intelligence, concerns about reliability, and fears of job loss.

4.2 Technological developments and the part played by AI in advancement of passive design

Artificial intelligence transforms passive architecture by enhancing energy efficiency and maximizing building performance through advanced predictive modeling and intelligent automation [59]. AI-driven climate prediction systems have become revolutionary instruments in environmental modeling, providing unparalleled accuracy and insight in projecting future climatic scenarios. These improvements empower architects and engineers to create structures that are both adaptive to present environmental requirements and durable to expected climatic variations. Utilizing AI-driven simulations, designers can methodically enhance essential characteristics, including insulation thickness, natural ventilation routes, thermal mass allocation, and passive heating and cooling strategies [60]. This optimization technique promotes the construction of buildings with markedly improved energy efficiency, hence diminishing operational carbon emissions and lifecycle expenses. Moreover, the function of artificial intelligence in passive design extends beyond the design stage and encompasses the operational management of buildings. The growing incorporation of AI-driven building management systems (BMS) facilitates

real-time data acquisition, dynamic regulation of environmental systems, and anticipatory maintenance approaches [61]. These sophisticated technologies perpetually assess occupancy patterns, exterior weather conditions, and energy consumption metrics, constantly optimizing building operations to enhance comfort and energy efficiency. Thus, AI-driven BMS systems are becoming integral elements of passive design frameworks, guaranteeing ongoing efficiency and environmental adaptability throughout a building. These systems use real-time data processing to control and optimize energy consumption based on user activity and external temperature. Machine learning algorithms improve automation through dynamic adjustments of shading devices, optimization of indoor temperatures, and management of ventilation systems to ensure superior air quality and thermal comfort. These structures reduce energy consumption through artificial intelligence while maintaining ideal indoor environmental conditions. Additionally, the role of artificial intelligence in material science and innovation is becoming more crucial. Researchers are employing AI-assisted methods to develop sustainable building materials that enhance insulation properties and reduce reliance on non-renewable resources [62]. Passive house construction is made more efficient through innovations like phase-change materials, adaptable façades, and bio-based insulation, all optimized by artificial intelligence to support sustainability. Integrating artificial intelligence into material selection and lifecycle analysis can assist builders and architects in creating structures that maximize energy efficiency while adhering to strict environmental standards [63]. Despite these advancements, the successful integration of artificial intelligence in passive design relies on close multidisciplinary collaboration among technical developers, architects, urban designers, and policymakers. Standardized frameworks and guidelines must be established to ensure that AI-based solutions meet structural and environmental safety requirements. Furthermore, ongoing research and innovation must make passive design more affordable and accessible to a broader range of users, supported by artificial intelligence.

4.3 Public and corporate sector contributions to passive design integrated with sustainable AI

4.3.1 Government support of passive design integrated with AI

The extensive adoption of passive design solutions, especially those augmented by artificial intelligence (AI), is significantly dependent on proactive governmental backing and specific financial measures [64, 65]. Policymakers are crucial in enabling this transformation by implementing extensive financial incentives, such as tax credits, grants, and subsidies, targeted at developers and stakeholders who incorporate AI-driven solutions in passive building projects. These strategies not only mitigate the financial strain of initial investments but also promote enduring dedication to sustainable construction techniques. Furthermore, the integration of AI-enhanced passive design concepts into national building codes, urban planning frameworks, and regulatory standards is crucial for establishing a solid legal and structural base that promotes wider adoption. This regulatory congruence indicates governmental support, diminishes uncertainty for developers, and hastens the adoption of innovative, ecologically sustainable building technology within the construction industry. This integrated strategy guarantees that economic and legislative frameworks operate in harmony to foster sustainability and technical progress in the built environment [66]. Performance-based incentives enable governments to reward structures exhibiting

outstanding energy efficiency, especially with AI-augmented passive technologies. The ongoing progress of passive design combined with artificial intelligence relies on persistent investment in research and development, promoting advancements in predictive modeling, adaptive control systems, and material advances. Governmental promotion of innovation should focus on fostering collaboration among industry players, research institutions, and academic entities, thereby enhancing interdisciplinary knowledge transfer and expediting the implementation of advanced solutions. Moreover, academic institutions are crucial in this context by integrating specialized courses on artificial intelligence applications in sustainable design and construction into the curricula of engineering, architecture, and environmental science. This educational investment will prepare future professionals with the essential skills to proficiently implement AI-driven techniques, guaranteeing that sustainability objectives are achieved with technical accuracy and ethical accountability.

4.3.2 Private sector and technological advancements in passive design driven by AI

The private sector is also vital for developing passive design, including artificial intelligence. From environmental and financial angles, smart buildings driven by artificial intelligence appeal to real estate developers and construction companies more and more [67]. Rising awareness of global sustainability will increase demand for passive houses improved by artificial intelligence, promoting private investment in this field. By offering competitively priced, technologically advanced, energy-efficient homes, developers applying AI-based design approaches may stand out in the crowded real estate market. Artificial intelligence technology businesses' activities will help improve the accessibility and efficiency of passive design (**Table 2**). Exciting prospects to increase the scalability and feasibility of passive design solutions come from emerging digital twin technologies, intelligent monitoring systems, and AI-powered energy management platforms [68]. Technology companies and the building industry, taken together, can hasten the acceptance of AI-driven energy efficiency solutions, therefore supporting a more sustainable built environment. The integration of artificial intelligence (AI) with passive design signifies a crucial progression in the creation of sustainable and energy-efficient structures. The capacity of AI to optimize building orientation, material selection, ventilation techniques, and energy consumption predictions improves passive design principles through real-time decision-making and predictive analysis. However, to fully actualize this integration, ongoing innovation in AI algorithms and computational models is essential, especially in domains like generative design and digital twin simulations. A multi-stakeholder strategy is crucial, necessitating the involvement of government agencies, commercial sector organizations, and academic research institutions [69]. Policymakers are essential in creating strong legislative frameworks that promote sustainable construction practices and tackle issues of data privacy, interoperability, and standardization. Likewise, focused governmental financing for AI and sustainability research, in conjunction with private investment, will expedite technical advancement and market integration. Moreover, promoting market-oriented solutions like certification systems for AI-optimized passive buildings and financial incentives for developers might facilitate the shift from theoretical study to extensive implementation. This comprehensive strategy can elevate artificial intelligence-enhanced passive design from a nascent invention to a mainstream element of modern architecture, fostering energy efficiency and environmental responsibility on both local and global scales [70]. **Table 4** delineates the fundamental aspects facilitating the advancement

of AI-augmented passive design. It emphasizes the private sector’s role, increasing market demand, and contributions from technology firms (**Table 3**). Essential technologies, such as digital twins and AI energy management platforms, are vital for scalability. Ongoing innovation, cooperative engagement among stakeholders, robust policies, and financial incentives combine to expedite widespread adoption, targeting sustainable, energy-efficient buildings at both local and global scales (**Table 4**).

Aspect	Key features	Challenges	Opportunities
Intelligent temperature control and adaptive environmental management	IoT-connected HVAC systems employ AI-driven algorithms to monitor and adjust temperature, humidity, and air quality; smart thermostats synchronize with occupancy and weather patterns; and dynamic shading technologies manage light and temperature levels.	High initial installation and maintenance costs, concerns about data privacy and security breaches, and interoperability challenges among various smart devices.	Improved energy efficiency results in cost savings, enhances occupant comfort and health, and supports sustainable living by reducing energy consumption.
Highly developed home security and hazard detection	AI-enabled surveillance systems featuring facial recognition, motion sensors, and high-resolution cameras; automated alarm systems and smart locks; and biometric access control with remote authorization management.	Potential cybersecurity threats and hacking risks, privacy concerns related to continuous surveillance, and dependency on stable internet connections and power supply.	Enhanced security and peace of mind for homeowners; quicker and more effective threat detection and response; and possible collaboration with law enforcement and emergency services for swift assistance.
Emergency response and fire protection integration	IoT-driven smoke and gas leak detection systems offer real-time monitoring, automate emergency responses such as HVAC shutoff, exit unlocking, and emergency lighting activation, and feature centralized IoT architecture for seamless device integration.	The reliability of automated emergency responses, the risk of false alarms leading to unnecessary interventions, and the compatibility and integration challenges with existing fire safety systems.	Decrease in fire-related damage and casualties; improved response times and coordination during emergencies; and potential for integrating smart city infrastructure to enhance public safety.

Table 2.
Difficulties and prospects in using smart technologies for comfort and security.

Policy challenge	Description	Key challenges
High costs and financial barriers	Expensive initial investment, reliance on advanced AI and imported materials, and lack of financial support.	High upfront costs, hard to get funding, and no incentives.
Social and cultural resistance	People and professionals see AI solutions as too complex or risky, with fears of job loss and mistrust.	Resistance to change, misunderstanding AI, and job concerns.

Table 3.
Financial and social barriers affecting policy challenges in AI-integrated passive design.

Area	Key point	Impact
Private sector	Developers use AI for smart, energy-efficient buildings	Competitive advantage in real estate market
Market demand	Sustainability awareness increases	More investment in AI-based passive houses
Tech companies	Improve accessibility and efficiency of passive design	Faster adoption of AI technologies
Key technologies	Digital twins, monitoring systems, and AI energy management	Scalable and practical solutions for buildings
AI benefits	Optimizes design, materials, and energy use	Better passive design through real-time decisions
Innovation need	Ongoing development of AI models and simulations	Keeps improving AI's contribution to passive design
Collaboration	Governments, companies, universities must cooperate	Faster progress and adoption
Policies	Need laws and frameworks for data and standards	Supports safe, large-scale implementation
Incentives	Funding, certifications, and financial support	Easier transition from idea to reality
Outcome	Mainstream AI-enhanced sustainable buildings	Energy-efficient, eco-friendly cities worldwide
Market demand	Sustainability awareness increases	More investment in AI-based passive houses
Tech companies	Improve accessibility and efficiency of passive design	Faster adoption of AI technologies

Table 4.
Principal factors influencing AI-enhanced passive design development.

5. Conclusions

Passive architectural design is a synergistic strategy that transforms buildings into intelligent systems empowered by real-time data. Therefore, changing human and environmental needs requires benefiting from data collected, refined, and analyzed using AI-powered technologies such as ML and IoT. In addition to data analysis, these technologies are able to build models able to predict futuristic needs and make decisions that enhance users' comfort on one hand and energy efficiency on the other hand.

The study focuses on three main areas in which AI-driven technologies are redefining passive architecture: predictive modeling for optimizing façade configuration, smart materials with sensors embedded within them for real-time thermal regulation, and IoT-enabled control for customizable indoor comfort. Together, these three domains illustrate how intelligent AI-powered systems can autonomously manage the indoor environment by controlling natural lighting, ventilation, and temperature, minimizing buildings' energy dependency while maximizing buildings' responsiveness. Consequently, the findings indicate a decisive need to move toward buildings that are not only sustainable but also participatory and user-centered.

The inclusion of (AI), (ML), and (IoT) with passive design indicates a remarkable paradigm shift in conceiving buildings—not only as static structures but more as living systems within broader urban ecologies. This shift holds profound implications

for reducing energy demand, underpinning occupant agency, and aligning architectural design strategies with climatic resilience and data-driven transformation. Despite the promising advancement of AI-enhanced passive systems, limited empirical validation at large scale, high implementation costs, and inequitable access across different global contexts require comprehensive policy-related changes at multiple levels, exacerbating the complexity of the decision-making process in the built environment.

In summary, AI-integrated passive design for enhancing passive buildings' performance invites policymakers to develop more supportive frameworks that attract stakeholders to invest in these technologies. Furthermore, wide-scale interdisciplinary research is essential to accelerate this technological transformation. Consequently, embracing this trajectory defines a new era of architecture that is not only energy-efficient but also attuned to environmental, social, and ecological requirements.

Conflict of interest

The authors declare no conflict of interest.

Author details

Sudaff Mohammed^{1*}, Duha A. Jebur² and Zahraa M. Ibrahim²

1 Department of Techniques of Interior Design, Al-Kunooze University, College of Applied Arts, Basrah, Iraq

2 Department of Architecture, Basrah University, College of Engineering, Basrah, Iraq

*Address all correspondence to: ae.21.22@grad.uotechnology.edu.iq

IntechOpen

© 2025 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. 

References

- [1] Buhaug H, Urdal H. An urbanization bomb? Population growth and social disorder in cities. *Global Environmental Change*. 2013;**23**(1):1-10. DOI: 10.1016/j.gloenvcha.2012.10.016
- [2] Anjum KN et al. Exploring the multifaceted impact of artificial intelligence and the Internet of Things on Smart City management. *Journal of Computer Science and Technology Studies*. 2024;**6**(1):241-248. DOI: 10.32996/jcsts.2024.6.1.28
- [3] Cao X, Dai X, Liu J. Building energy-consumption status worldwide and the state-of-the-art technologies for zero-energy buildings during the past decade. *Energy and Buildings*. 2016;**128**:198-213. DOI: 10.1016/j.enbuild.2016.06.089
- [4] Rane N. Integrating leading-edge artificial intelligence (AI), Internet of Things (IoT), and big data technologies for smart and sustainable architecture, engineering and construction (AEC) industry: Challenges and future directions. *International Journal of Data Science and Big Data Analytics*. 2023;**3**(2):73-95. DOI: 10.51483/ijdsbda.3.2.2023.73-95
- [5] Zafar A. Reconciling blockchain technology and data protection laws: Regulatory challenges, technical solutions, and practical pathways. *Journal of Cybersecurity*. 2025;**11**(1):2-20. DOI: 10.1093/cybersec/tyaf002
- [6] Di Stefano AG, Ruta M, Masera G. Advanced digital tools for data-informed and performance-driven design: A review of building energy consumption forecasting models based on machine learning. *Applied Sciences*. 2023;**13**(24):12981. DOI: 10.3390/app132412981
- [7] Elwy I, Hagishima A. The artificial intelligence reformation of sustainable building design approach: A systematic review on building design optimization methods using surrogate models. *Energy and Buildings*. 2024;**323**:114769. DOI: 10.1016/j.enbuild.2024.114769
- [8] Chenari B, Carrilho JD, da Silva MG. Towards sustainable, energy-efficient and healthy ventilation strategies in buildings: A review. *Renewable and Sustainable Energy Reviews*. 2016;**59**:1426-1447. DOI: 10.1016/j.rser.2016.01.074
- [9] Ogundiran J, Asadi E, da Silva MG. A systematic review on the use of AI for energy efficiency and indoor environmental quality in buildings. *Sustainability*. 2024;**16**(9):3627. DOI: 10.3390/su16093627
- [10] Almusaed A, Almssad A. Improvement of thermal insulation by environmental means. In: *Effective Thermal Insulation - The Operative Factor of a Passive Building Model*. London, UK: IntechOpen; 2012. pp. 1-22. DOI: 10.5772/35744
- [11] Gonçalves M, Figueiredo A, Almeida RMSF, Vicente R. Dynamic façades in buildings: A systematic review across thermal comfort, energy efficiency and daylight performance. *Renewable and Sustainable Energy Reviews*. 2024;**199**:114474. DOI: 10.1016/j.rser.2024.114474
- [12] Shan R, Junghans L. Multi-objective optimization for high-performance building facade design: A systematic literature review. *Sustainability*. 2023;**15**(21):15596. DOI: 10.3390/su152115596

- [13] Jo H, Lee J-K, Lee Y-C, Choo S. Generative artificial intelligence and building design: Early photorealistic render visualization of façades using local identity-trained models. *Journal of Computational Design and Engineering*. 2024;**11**(2):85-105. DOI: 10.1093/jcde/qwae017
- [14] Abdullah HK. Eastern Mediterranean University Cyprus. 2021. [Online]. Available: <http://hdl.handle.net/11129/5691> [Accessed: April 8, 2025]
- [15] Malayeri M, Bahri M, Haghighat F, Shah A. Impact of air distribution on indoor formaldehyde abatement with/without passive removal material: A CFD modeling. *Building and Environment*. 2022;**212**:108792. DOI: 10.1016/j.buildenv.2022.108792
- [16] Villano F, Mauro GM, Pedace A. A review on machine/deep learning techniques applied to building energy simulation, optimization and management. *Thermo*. 2024;**4**(1):100-139. DOI: 10.3390/thermo4010008
- [17] Kośny J. PCM-Enhanced Building Components. Cham, Switzerland: Springer; 2015. DOI: 10.1007/978-3-319-14286-9
- [18] Shboul B et al. Energy and economic analysis of building integrated photovoltaic thermal system: Seasonal dynamic modeling assisted with machine learning-aided method and multi-objective genetic optimization. *Alexandria Engineering Journal*. 2024;**94**:131-148. DOI: 10.1016/j.aej.2024.03.049
- [19] Cannavale A et al. Smart electrochromic windows to enhance building energy efficiency and visual comfort. *Energies*. 2020;**13**(6):1449. DOI: 10.3390/en13061449
- [20] Liu X, Yupeng W. A review of advanced architectural glazing technologies for solar energy conversion and intelligent daylighting control. *Architectural Intelligence*. 2022;**1**(1):1-10. DOI: 10.1007/s44223-022-00009-6
- [21] Massaro A. Intelligent materials and nanomaterials improving physical properties and control oriented on electronic implementations. *Electronics*. 2023;**12**(18):3772. DOI: 10.3390/electronics12183772
- [22] Ruggiero S et al. Energy saving through building automation systems: Experimental and numerical study of a smart glass with liquid crystal and its control logics in summertime. *Energy and Buildings*. 2022;**273**:112403. DOI: 10.1016/j.enbuild.2022.112403
- [23] Mellit A. Artificial intelligence technique for modelling and forecasting solar radiation data: A review. *International Journal of Artificial Intelligence and Soft Computing*. 2008;**1**(1):52-76. DOI: 10.1504/IJAISC.2008.021264
- [24] Ascione F et al. Energy demand and air quality in social housing buildings: A novel critical review. *Energy and Buildings*. 2024;**319**:114542. DOI: 10.1016/j.enbuild.2024.114542
- [25] Ajayi F et al. AI-driven decarbonization of buildings: Leveraging predictive analytics and automation for sustainable energy management. *World Journal of Advanced Research and Reviews*. 2024;**24**(1):061-079. DOI: 10.30574/wjarr.2024.24.1.2997
- [26] Loonen RC et al. Climate adaptive building shells: State-of-the-art and future challenges. *Renewable and Sustainable Energy Reviews*. 2013;**25**:483-493. DOI: 10.1016/j.rser.2013.04.016

- [27] Liu Z et al. Advanced controls on energy reliability, flexibility and occupant-centric control for smart and energy-efficient buildings. *Energy and Buildings*. 2023;**297**:113436. DOI: 10.1016/j.enbuild.2023.113436
- [28] Moon JW et al. Comparative study of artificial intelligence-based building thermal control methods—application of fuzzy, adaptive neuro-fuzzy inference system, and artificial neural network. *Applied Thermal Engineering*. 2011;**31**(14):2422-2429. DOI: 10.1016/j.applthermaleng.2011.04.006
- [29] De Paola A et al. Intelligent management systems for energy efficiency in buildings: A survey. *ACM Computing Surveys (CSUR)*. 2014;**47**(1):1-38. DOI: 10.1145/2611779
- [30] Uzoka A, Cadet E, Ojukwu PU. The role of telecommunications in enabling Internet of Things (IoT) connectivity and applications. *Comprehensive Research and Reviews in Science and Technology*. 2024;**2**(02):055-073. DOI: 10.57219/crrst.2024.2.2.0037
- [31] Fakhabi MM, Hamidian SM, Aliehyaei M. Exploring the role of the Internet of Things in green buildings. *Energy Science & Engineering*. 2024;**12**(9):3779-3822. DOI: 10.1002/ese3.1840
- [32] Hasan Z et al. Smart ventilation systems for real-time pollution control: A review of ai-driven technologies in air quality management. *Frontiers in Applied Engineering and Technology*. 2024;**1**(01):22-40. DOI: 10.3389/fapet.2024.00003
- [33] Chua KJ et al. Achieving better energy-efficient air conditioning—A review of technologies and strategies. *Applied Energy*. 2013;**104**:87-104. DOI: 10.1016/j.apenergy.2012.10.037
- [34] Pisharoty D, Yang R, Newman M, Whitehouse K. Thermocoach: Reducing home energy consumption with personalized thermostat recommendations. 201-210. In: 2nd ACM International Conference on Embedded Systems for Energy-Efficient Built Environments, Seoul. 2015. DOI: 10.1145/2821650.2821671
- [35] Terence KL, Hui R, Sherratt S, Sánchez DD. Major requirements for building smart homes in smart cities based on Internet of Things technologies. *Future Generation Computer Systems*. 2017;**76**:358-369. DOI: 10.1016/j.future.2016.10.026
- [36] Odiyur Vathanam GS et al. A review on effective use of daylight harvesting using intelligent lighting control systems for sustainable office buildings in India. *Sustainability*. 2021;**13**(9):4973. DOI: 10.3390/su13094973
- [37] Kirwan CG, Zhiyong F. *Smart Cities and Artificial Intelligence: Convergent Systems for Planning, Design, and Operations*. Elsevier; 2020. DOI: 10.1016/C2018-0-01594-7. Available from: <https://bit.ly/3S5Rv74>
- [38] Kirpalani C. Technology-driven approaches to enhance disaster response and recovery. In: *Geospatial Technology for Natural Resource Management*. Massachusetts: Scrivener, Beverly; 2024. pp. 25-81. DOI: 10.1002/9781394167494.ch2
- [39] Wang Z et al. A survey on IoT-enabled home automation systems: Attacks and defenses. *IEEE Communications Surveys & Tutorials*. 2022;**24**(4):2292-2328. DOI: 10.1109/COMST.2022.3182613

- [40] Varshini M. Fire secure using chain mechanism and IOT. Management (JOIREM). 2024;**10**(4):1-57 Available from: <http://bit.ly/43Pyw7W>
- [41] Jose A, Malekian R. Smart home automation security: A literature review. SmartCR. 2015;**5**(4):269-285. DOI: 10.6029/smartcr.2015.04.004
- [42] Talal M et al. Smart home-based IoT for real-time and secure remote health monitoring of triage and priority system using body sensors: Multi-driven systematic review. Journal of Medical Systems. 2019;**43**:1-34. DOI: 10.1007/s10916-019-1158-z
- [43] Franceschini L, Midali A. Industrial IoT: A Cost-Benefit Analysis of Predictive Maintenance Service. Polytecnico, Milano: ING - School of Industrial and Information Engineering [Online] 2019. Available from: <http://bit.ly/3FXCmC9> [Accessed: April 8, 2025]
- [44] Arockiasamy FS et al. A comprehensive review of real-time monitoring and predictive maintenance techniques: Revolutionizing natural fibre composite materials maintenance with IoT. Pertanika Journal of Science & Technology. 2023;**31**:87-110. DOI: 10.47836/pjst.31.S1.05
- [45] Huang Y et al. The optimization of agricultural irrigation based on big data: An integrated analysis of climate conditions, water resources, soil types, and crop demand. Advances in Resources Research. 2025;**5**(1):386-413. DOI: 10.50908/arr.5.1_386
- [46] Alizadehtazi B, Gurian PL, Montalto FA. Observed variability in soil moisture in engineered urban green infrastructure systems and linkages to ecosystem services. Journal of Hydrology. 2020;**590**:125381. DOI: 10.1016/j.jhydrol.2020.125381
- [47] Rehan H. Internet of Things (IoT) in smart cities: Enhancing urban living through technology. Journal of Engineering and Technology. 2023;**5**(1):1-16. DOI: 10.9756/IAJSE/V1111/IAJSE1127
- [48] Almusaed A, Yitmen I. Architectural reply for smart building design concepts based on artificial intelligence simulation models and digital twins. Sustainability. 2023;**15**(6):4955. DOI: 10.3390/su15064955
- [49] Omer AM. Renewable building energy systems and passive human comfort solutions. Renewable and Sustainable Energy Reviews. 2008;**12**(6):1562-1587. DOI: 10.1016/j.rser.2006.07.010
- [50] Ahmed I et al. A review on enhancing energy efficiency and adaptability through system integration for smart buildings. Journal of Building Engineering. 2024;**89**:109354. DOI: 10.1016/j.jobe.2024.109354
- [51] Chen X, Yang H, Lin L. A comprehensive review on passive design approaches in green building rating tools. Renewable and Sustainable Energy Reviews. 2015;**50**:1425-1436. DOI: 10.1016/j.rser.2015.06.003
- [52] Challoumis C. AI'S role IN the cycle of money. In: XIX International Scientific Conference. London: Great Britain; 2024 Available from: <https://bit.ly/3RboMNP>
- [53] Mills E et al. From volatility to value: Analysing and managing financial and performance risk in energy savings projects. Energy Policy. 2006;**34**(2):188-199. DOI: 10.1016/j.enpol.2004.08.042
- [54] Regona M et al. Opportunities and adoption challenges of AI in the construction industry: A PRISMA review. Journal of Open Innovation: Technology,

Market, and Complexity. 2022;8(1):45. DOI: 10.3390/joitmc8010045

[55] Dalle J, Aydin H, Wang CX. Cultural dimensions of technology acceptance and adaptation in learning environments. *Journal of Formative Design in Learning*. 2024;8(6):1-14. DOI: 10.1007/s41686-024-00095-x

[56] Zhang Y, Deng B. Exploring the nexus of smart technologies and sustainable ecotourism: A systematic review. *Heliyon*. 2024;10(11):2-21. DOI: 10.1016/j.heliyon.2024.e31996

[57] Clark R, Reed J, Sunderland T. Bridging funding gaps for climate and sustainable development: Pitfalls, progress and potential of private finance. *Land Use Policy*. 2018;71:335-346. DOI: 10.1016/j.landusepol.2017.12.013

[58] Tschang T, Mezquita EA. Artificial intelligence as augmenting automation: Implications for employment. *Academy of Management Perspectives*. 2021;35(4):642-659. DOI: 10.5465/amp.2019.0062

[59] Farzaneh H et al. Artificial intelligence evolution in smart buildings for energy efficiency. *Applied Sciences*. 2021;11(2):763. DOI: 10.3390/app11020763

[60] Rane N, Choudhary S, Rane J. Integrating ChatGPT, bard, and leading-edge generative artificial intelligence in building and construction industry: Applications, framework, challenges, and future scope. *SSRN Electronic Journal*. 2023;3(2):92-124. DOI: 10.2139/ssrn.4645597

[61] Hanafi AM, Moawed MA, Abdullatif OE. Advancing sustainable energy management: A comprehensive review of artificial intelligence techniques in building. *Engineering*

Research Journal (Shoubra). 2024;53(2):26-46. DOI: 10.21608/erjsh.2023.226854.1196

[62] Almusaed A, Yitmen I, Almssad A. Reviewing and integrating aec practices into industry 6.0: Strategies for smart and sustainable future-built environments. *Sustainability*. 2023;15(18):13464. DOI: 10.3390/su151813464

[63] Rane N, Choudhary SP, Rane J. Enhancing sustainable construction materials through the integration of generative artificial intelligence, such as ChatGPT. *Sustainable and Clean Buildings*. 2024;1(1):98-122. DOI: 10.2139/ssrn.4681678

[64] Almusaed A, Yitmen I, Almssad A. Enhancing smart home design with AI models: A case study of living spaces implementation review. *Energies*. 2023;16(6):2636. DOI: 10.3390/en16062636

[65] Brundage M et al. The malicious use of artificial intelligence: Forecasting, prevention, and mitigation. *Apollo - University of Cambridge Repository*. DOI: 10.17863/CAM.22520

[66] Ujager FS. Sustainable sustainability: A holistic approach. In: *Exploring Pillars of Sustainability for Modern Age Improvements*. IGI Global Scientific Publishing; 2025. pp. 1-16. DOI: 10.4018/979-8-3693-5748-4. Available from: <https://www.igi-global.com/gateway/chapter/365296>

[67] Emad S et al. The role of artificial intelligence in developing the tall buildings of tomorrow. *Buildings*. 2025;15(5):749. DOI: 10.3390/buildings15050749

[68] Agostinelli S. Optimization and Management of Microgrids in the Built Environment Based on Intelligent

Digital Twins. Doctoral thesis, Sapienza
Universita Di Roma [Online]; 2024.
Available from: <https://bit.ly/4loJSWK>
[Accessed: April 9, 2025]

[69] Nonet GA-H et al. Multi-stakeholder
engagement for the sustainable
development goals: Introduction to the
special issue. *Journal of Business Ethics*;
2022;**180**(4):945-957. DOI: 10.1007/
s10551-022-05192-0

[70] Tejchman, F. Insulating
Modernism: Isolated and Non-isolated
Thermodynamics in Architecture.
Journal of Architectural Education.
Birkhäuser; 2015;**69**(2):233-234. DOI:
10.1080/10464883.2015.1063900

Smart City Innovations in South Korea: Lessons for Emerging Economies

Jae Eun You

Abstract

As global cities face mounting challenges from rapid urbanization, climate change, and digital transformation, the smart city paradigm has emerged as a strategic framework for sustainable and inclusive urban development. This chapter examines South Korea's experience as a leading smart city innovator, analyzing how a state-led, technology-driven, and increasingly citizen-centered model has evolved through coordinated governance and pilot experimentation. Drawing on national policies, institutional reports, and case studies of Sejong and Busan Eco Delta City, this chapter explores nine interlinked themes: conceptual foundations, legal frameworks, innovation domains, implementation challenges, and global applicability. Korea's innovation domains—smart mobility, living, environment, economy, governance, citizen participation, and architecture—are implemented through integrated data platforms, urban operating systems, and cross-sector public-private partnerships. Sejong represents a citizen-oriented urban testbed emphasizing autonomous mobility, AI-driven public services, and participatory governance. In contrast, Busan demonstrates environmental resilience and fintech integration in a waterfront urban model. Despite substantial achievements, Korea's smart city development encounters persistent implementation barriers, including fragmented governance, data siloing, and imbalanced public-private dynamics. These constraints underscore the need for more decentralized innovation ecosystems, adaptive regulatory mechanisms, and inclusive digital governance structures. For emerging economies, Korea's experience offers adaptable policy insights, particularly for countries in ASEAN and the Middle East. However, successful transfer depends on local capacity, regulatory readiness, and sociopolitical context. The chapter concludes with actionable policy recommendations on decentralization, interoperable data platforms, and citizen engagement to support more equitable, resilient, and future-ready smart city transitions.

Keywords: urban planning, infrastructure, smart city development, governance, sustainability

1. Introduction

As cities around the world grapple with mounting pressures from climate change, rapid urbanization, aging infrastructure, and social inequality, the concept of the

“smart city” has emerged as a prominent framework for reimagining urban life. A smart city is not simply defined by its technological infrastructure but by its ability to leverage data, connectivity, and innovation to enhance the quality of life, improve governance efficiency, and foster sustainable development. From transportation and energy to public safety and healthcare, smart cities aspire to integrate digital technologies into every layer of urban functioning. However, the success of such integration depends not only on technological capacity but also on political leadership, institutional coordination, and citizen engagement.

South Korea stands out as a global frontrunner in smart city innovation. Building upon its early investments in information and communication technologies (ICT) and its highly urbanized society, the country has positioned itself at the vanguard of digital urban transformation. What sets South Korea apart is its comprehensive, state-led approach to smart city development. Unlike many Western countries where smart city initiatives are often fragmented and locally driven, South Korea has pursued a top-down yet adaptive model in which central government ministries coordinate with local governments, private sector innovators, and academic institutions. This coordinated effort has culminated in the establishment of nationally designated smart city pilot projects that serve as experimental testbeds for future urban models.

The trajectory of South Korea’s smart city strategy reflects a gradual evolution in both concept and implementation. The early 2000s witnessed the rise of the “Ubiquitous City” (U-City) model, which emphasized the embedding of digital sensors and networks across the urban landscape. While technologically advanced, these early efforts were often criticized for being overly infrastructure-focused and insufficiently responsive to the lived needs of citizens. Recognizing these limitations, South Korea enacted the Smart City Act in 2024 [1], which marked a significant policy shift toward data-driven and citizen-centric urban innovation. The Act laid the legal and institutional foundation for smart city development, emphasizing open data platforms, interoperability, participatory governance, and public-private collaboration.

Flagship projects such as the Sejong National Smart City and the Busan Eco Delta Smart City exemplify this integrated approach. These projects aim to develop “living laboratories” where real-time data collection, artificial intelligence, autonomous mobility, and green energy systems converge to create adaptive and resilient urban environments. For example, in Sejong, the government has implemented a decentralized mobility-as-a-service (MaaS) ecosystem, integrating autonomous shuttles with digital infrastructure. In Busan, water management, energy efficiency, and fintech-based urban services are being deployed through a cross-sectoral, platform-oriented model. These initiatives are not isolated technological showcases but are deeply embedded within broader national development strategies, including the Korean New Deal and the Digital Platform Government initiative (**Table 1**).

Importantly, South Korea’s experience offers a rich set of insights for emerging economies. Many developing countries are currently facing urban challenges similar to those that South Korea experienced during its rapid industrialization in the 1970s and 1980s, such as congestion, pollution, informal settlements, and limited access to public services. In this context, South Korea’s model demonstrates how technological leapfrogging, when combined with coordinated governance and institutional reform, can enable more sustainable and inclusive urban development. Furthermore, Korea’s emphasis on iterative learning, policy experimentation, and stakeholder co-creation offers an alternative to purely market-driven or technology-centric approaches that have often failed in lower-capacity settings.

Post-materialism	Decentralization	Smart technologies
Lifestyle, work-life balance	Sharing, openness, decentralization	Data-driven systems and AI
Human-centered and eco-friendly	Respect for diversity and citizen participation	Creative innovation

Table 1.
The future city vision pursued by Sejong Smart City.

Nevertheless, the transferability of the Korean smart city model is not without limitations. The country’s high level of digital literacy, robust telecommunications infrastructure, and relatively centralized administrative structure are not easily replicable in all contexts. Therefore, while the Korean case provides a compelling template, it must be adapted with sensitivity to local political economies, cultural norms, and governance capacities in the Global South.

This chapter aims to critically examine South Korea’s smart city policy framework, technological innovations, and implementation strategies. Drawing on national-level policy documents, urban case studies, and comparative smart city research, the chapter explores how Korea’s experience can inform urban development in emerging economies. Specifically, it analyzes the evolution of policy instruments, the role of public-private partnerships, the integration of data governance, and the mechanisms of citizen participation. It also highlights key lessons for capacity-building, regulatory alignment, and institutional innovation in developing contexts.

In doing so, the chapter contributes to the growing body of interdisciplinary scholarship on smart cities by situating the Korean case within a global discourse. More than a case study, South Korea’s smart city development can be understood as a dynamic policy experiment that blends technological optimism with governance pragmatism. As cities worldwide seek to balance innovation with equity, South Korea’s experience offers both inspiration and cautionary guidance for designing the urban futures of tomorrow.

2. Conceptual foundations of smart cities

The concept of the smart city has evolved significantly over the past two decades, shaped by advancements in digital technology, urban policy, and the increasing complexity of city management. Originally associated with the integration of information and communication technologies (ICT) into urban infrastructure, the term “smart city” now encompasses a much broader paradigm that includes sustainability, citizen participation, data-driven governance, and innovation ecosystems [2, 3].

South Korea’s conceptual approach to smart cities is rooted in its developmental experience and its commitment to leveraging digital technologies for the public good. According to the Korean Smart City Act [1], a smart city is defined as a city that improves citizens’ quality of life and promotes sustainable development through the intelligent integration of infrastructure and services using ICT. This definition reflects both technological ambitions and policy orientation toward inclusive growth.

Based on a synthesis of international literature and domestic evaluations [4], smart cities are typically characterized by six core domains: smart mobility, smart environment, smart people, smart living, smart governance, and smart economy. In South Korea, these domains have been expanded into eight thematic areas to reflect

national priorities: mobility, living, environment, citizens, government, economy, architecture & technology, and fintech [3].

Each domain is supported by key enabling technologies such as big data analytics, cloud computing, artificial intelligence, and the Internet of Things (IoT). For instance, smart mobility includes autonomous vehicle integration, intelligent transport systems, and real-time public transit management. Smart environment focuses on energy efficiency, disaster risk management, and green infrastructure. These domains are interconnected and often governed by integrated data platforms designed to ensure interoperability across sectors.

A critical component of South Korea's conceptual foundation is the emphasis on data as public infrastructure. The transition from U-City to smart city paradigms marks a move away from hardware-centric infrastructure toward platform-based data ecosystems. The government has promoted open data standards, citizen feedback systems, and public-private partnerships to strengthen urban resilience and policy responsiveness [3, 5].

However, scholars have cautioned that an overemphasis on technology without corresponding institutional reform can lead to ineffective outcomes. Ismagilova et al. [2] highlighted that successful smart cities must be grounded in governance structures that promote transparency, citizen engagement, and cross-sectoral collaboration. South Korea's policy evolution reflects this shift, with newer initiatives placing greater focus on participatory planning, regulatory innovation, and digital inclusion.

In summary, South Korea's conceptualization of smart cities integrates technological sophistication with institutional design. This dual emphasis enables cities to not only deploy cutting-edge technologies but also develop governance mechanisms that make innovation sustainable and inclusive. This foundation provides a valuable model for other nations seeking to design holistic and future-ready urban systems.

3. Evolution of smart city policies in South Korea

South Korea's national smart city policy has undergone a significant transformation over the past two decades, transitioning from early-stage digital infrastructure projects to holistic, data-driven urban governance. This evolution reflects the country's broader commitment to digital innovation as a tool for socioeconomic development and environmental sustainability [3]. At the heart of this strategy is the integration of technology into public services, urban planning, and citizen engagement frameworks.

The Korean government's strategic intervention began in the early 2000s with the launch of U-City (ubiquitous city) projects. These initiatives sought to embed ICT in urban infrastructure, focusing on networked buildings, sensor-based traffic control, and basic e-governance services. While U-City represented a major step forward, it was criticized for being technology-centric and lacking human-centered design. Recognizing these limitations, the government shifted its focus through the Smart City Act of 2024, which formalized a national commitment to building cities that enhance quality of life through innovation, sustainability, and inclusive governance [1].

A major outcome of this legislative shift was the designation of two National Pilot Smart Cities: Sejong and Busan. These cities serve as experimental platforms for testing next-generation urban technologies and policy models. The Sejong National Smart City, located in the country's administrative capital, is designed as

a zero-energy city that integrates autonomous transportation, AI-enabled public services, and a citizen data hub. Its seven key innovation areas include smart mobility, healthcare, education, energy, and participatory governance [5].

In contrast, the Busan Eco Delta Smart City is a waterfront urban district focused on environmental resilience and fintech innovation. This city emphasizes water recycling, renewable energy, and intelligent housing systems, positioning itself as a model for climate-adaptive urban development. One of its most unique features is the integration of fintech services for public resource allocation and smart contracts, which are being tested in real-time with citizen input [5].

Beyond these two flagship projects, the Korean government has initiated several other smart city programs, including the Smart City Challenge, which encourages regional governments and startups to co-develop tailored solutions for urban problems. The challenge has led to the creation of smart mobility systems in Daejeon, AI-based crime prediction platforms in Daegu, and citizen-led disaster response tools in Gwangju. These initiatives demonstrate the flexibility of Korea's approach and its capacity to adapt innovation to local contexts [3].

What differentiates South Korea's smart city strategy is the centralized coordination by the Ministry of Land, Infrastructure and Transport (MOLIT), in partnership with the Presidential Committee on the Fourth Industrial Revolution. This allows for resource pooling, legal standardization, and knowledge sharing across regions. Furthermore, public-private partnerships (PPPs) have been institutionalized through government-sponsored platforms that involve tech firms such as Samsung SDS, LG CNS, and KT Corporation in project design and implementation [3].

In summary, South Korea's smart city policy reflects a hybrid model that combines centralized planning with localized innovation. The national pilot projects in Sejong and Busan exemplify how such a model can foster experimentation, stakeholder participation, and system-wide learning. For emerging economies, these projects provide practical insights into how integrated governance, technological foresight, and institutional alignment can be leveraged to build future-ready cities.

4. Key domains of innovation

South Korea's smart city strategy is characterized by its comprehensive coverage of innovation domains that span across technological systems, institutional structures, and citizen-facing services. These domains form the backbone of smart city design and implementation, guiding both national-level projects and regionally tailored initiatives. Based on policy documents and evaluation frameworks [3, 5], South Korea categorizes smart city functions into seven interrelated domains: smart mobility, smart living, smart environment, smart economy, smart government, citizen engagement, and smart architecture and technology.

Smart mobility has been a foundational pillar of South Korea's urban innovation strategy. The integration of autonomous vehicles, real-time public transportation systems, and mobility-as-a-service (MaaS) platforms is being actively tested in cities like Sejong. These systems are supported by AI-driven traffic control, smart parking infrastructure, and data-sharing among transport modes. The overarching goal is to reduce congestion, improve safety, and enable inclusive access to mobility services. The Busan Eco Delta Smart City, for instance, includes a multi-modal transport network coordinated via a centralized digital platform, emphasizing energy efficiency and last-mile connectivity.

Smart living refers to the application of digital solutions in daily life activities such as housing, healthcare, education, and leisure. In Sejong, smart homes are equipped with IoT sensors that monitor energy consumption and environmental quality. Healthcare innovation includes telemedicine systems, wearable biometric devices, and AI-assisted diagnosis platforms. Smart education infrastructure has been piloted using personalized learning algorithms and virtual reality classrooms. These living innovations are aimed not only at improving convenience but also at enhancing social equity and well-being, particularly for aging and vulnerable populations.

Environmental sustainability is a key priority within Korean smart cities. The integration of green infrastructure, renewable energy systems, and disaster risk reduction mechanisms illustrates this domain. In Busan, flood-prone areas are monitored through real-time hydrological sensors, while smart water recycling systems ensure efficient resource use. Urban forests, rooftop gardens, and passive building design are promoted to reduce urban heat islands. Cities are also integrating carbon tracking and waste optimization systems into urban management platforms, aligned with national carbon neutrality goals.

South Korea's smart cities promote economic innovation through digital entrepreneurship, smart logistics, and creative industries. Fintech-enabled public services, such as blockchain-based citizen ID and urban budgeting systems, are being tested in Busan. Local economies are supported by smart markets, e-commerce incubators, and urban tech clusters. The Smart City Challenge Program has created platforms for collaboration between startups and municipal governments, accelerating the commercialization of urban tech solutions. These initiatives are designed to create inclusive economic ecosystems that foster both technological advancement and job creation.

Smart governance in Korea emphasizes data transparency, policy responsiveness, and citizen-centered service delivery. Government services are increasingly digitalized through open data portals, AI-based public query systems, and predictive analytics for administrative planning. Cities like Daegu and Daejeon have implemented automated licensing systems and integrated complaint platforms. A key component of this domain is the Digital Twin, a virtual representation of urban systems used for real-time simulation, decision support, and participatory planning. These platforms enable local authorities to anticipate problems and optimize responses using data-driven insights.

Perhaps the most critical yet complex domain is citizen engagement. Moving beyond technology acceptance, Korean smart cities aim to foster active participation through feedback platforms, digital literacy initiatives, and co-design workshops. In Sejong, residents can vote on local urban design issues via mobile apps linked to the city's governance system. Social inclusion programs are targeted at digitally marginalized groups, including the elderly and low-income households, to ensure equitable access to smart city services. This participatory turn is a response to earlier critiques of U-City models, which were seen as overly technocratic.

This domain encompasses the physical and digital infrastructure necessary to support smart systems. Architectural innovations include modular housing, energy-efficient building codes, and integrated sensor networks. Smart city architecture in Korea is designed not only for functionality but also for adaptability and resilience. The deployment of urban data platforms—such as City OS—and high-speed 5G networks forms the technological backbone that supports interoperability across all domains. Pilot cities like Sejong and Busan are also testing decentralized data architectures to enhance cybersecurity and citizen data sovereignty.

5. National pilot projects

Among the most ambitious components of South Korea's smart city policy are its two national pilot projects: the Sejong National Smart City and the Busan Eco Delta Smart City. These projects were launched under the Korean Smart City Act [1] to serve as experimental platforms for next-generation urban innovations. Designated by the Ministry of Land, Infrastructure and Transport (MOLIT), these pilot cities aim to demonstrate how advanced technologies, participatory governance, and sustainable planning can converge to build future-ready urban ecosystems. While both cities share overarching goals, their design philosophies, implementation strategies, and innovation priorities differ significantly, offering distinct models for smart city development.

Sejong, South Korea's administrative capital, was selected as a national smart city pilot site with the goal of building a zero-energy, autonomous, and fully integrated urban environment. As a planned city developed from scratch in the 2000s, Sejong presented an ideal canvas for testing radical urban innovations without the constraints of legacy infrastructure.

At the core of Sejong's model is the concept of "human-centered urbanism." The city's master plan is built around seven innovation areas: mobility, healthcare, education, energy, governance, culture, and safety. Smart mobility services, such as autonomous shuttles and real-time traffic control, are fully integrated with digital infrastructure. The city also supports mobility-as-a-service (MaaS) platforms that allow residents to plan, book, and pay for transport across multiple modes via a single app (**Figure 1**) [3, 6].

Healthcare services in Sejong utilize wearable biosensors, telemedicine platforms, and AI-assisted diagnostic tools, specially tailored for aging populations. In the education domain, personalized learning systems and virtual classrooms powered by AI are being deployed. Furthermore, Sejong features an integrated urban data platform (UDP) that collects and analyzes data from multiple sources—environmental sensors, mobility networks, and public services—to support evidence-based policymaking and participatory governance [5].

One of the distinguishing features of Sejong is its emphasis on citizen participation. The city's governance framework includes digital platforms for public feedback,

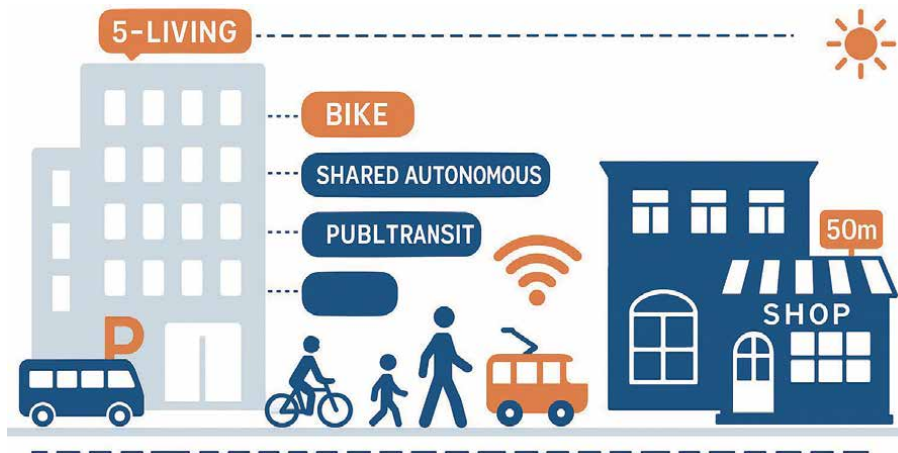


Figure 1.
Sejong Smart City mobility innovation platform.

Inclusive growth	The fourth industrial revolution technologies	Equitable opportunities
Culture and leisure	Environmental improvement and preservation	Democratic participation
Income and consumption	Safe living	Equal education
Family and community	Healthy city	

Table 2.
The future city vision pursued by Busan Eco Delta Smart City.

deliberative democracy tools, and co-design workshops. Residents are encouraged to contribute ideas and vote on urban planning decisions via mobile applications. These mechanisms address the early criticisms of South Korea’s U-City projects, which often excluded citizen voices.

In contrast to Sejong’s governmental focus, Busan Eco Delta Smart City (EDC) is envisioned as a climate-resilient urban district that integrates environmental innovation with digital finance infrastructure. Located on reclaimed waterfront land along the Nakdong River, the project covers approximately 11.8 square kilometers and is being developed as a sustainable, water-themed smart city (**Table 2**).

Busan EDC is particularly focused on water management, energy efficiency, and decentralized resource systems. Smart water grids monitor consumption in real time, while flood prediction and early warning systems use sensor data and climate models to prevent disasters. Homes and buildings are equipped with renewable energy technologies and adaptive designs that respond to environmental data, contributing to the city’s carbon neutrality targets.

What sets Busan apart is its incorporation of fintech into the smart city ecosystem. The city is testing blockchain-based urban budgeting, smart contracts for public procurement, and digital identity systems for accessing municipal services. Citizens can receive incentives for energy conservation or community engagement in the form of digital tokens, creating a gamified interaction between governance and behavior [5, 6].

Busan EDC also prioritizes social inclusion. Its Smart Village prototype includes rental smart housing for young adults, senior citizens, and low-income families, equipped with AI-powered accessibility features. Public-private partnerships with firms like LG CNS and KT Corporation are instrumental in piloting these innovations under real-world conditions.

The Sejong and Busan pilot cities offer two complementary visions of smart urbanism: one oriented toward administrative efficiency and citizen empowerment, the other toward environmental resilience and digital finance. Both highlight the importance of interoperability, stakeholder collaboration, and real-time data integration. Importantly, these projects demonstrate the need for adaptability—technological solutions must be customized to local geographies, socioeconomic conditions, and governance capabilities.

Moreover, these pilot projects emphasize the importance of institutional frameworks. The success of both cities is closely linked to legal support from the Smart City Act, centralized coordination by MOLIT, and financial backing from national R&D programs. These conditions may not exist in many emerging economies, but they underline the necessity of cross-sectoral alignment when attempting to replicate smart city models.

Ultimately, Sejong and Busan serve not only as testing grounds but also as knowledge hubs for other cities in South Korea and abroad. Their experiences provide valuable insights into the conditions under which smart cities can become not just technologically advanced, but also socially inclusive, environmentally resilient, and democratically governed.

6. Smart city implementation challenges

While South Korea has made significant progress in designing and piloting smart cities, the implementation process has not been without its challenges. These challenges are not solely technical in nature, but also institutional, organizational, and cultural. As the smart city paradigm shifts from isolated pilot projects to system-wide adoption, three critical areas have emerged as persistent bottlenecks: fragmented governance, limited data integration, and coordination difficulties within public-private partnerships (PPPs). Addressing these issues is vital for the long-term scalability and inclusiveness of smart city models both within South Korea and in emerging economies seeking to learn from its experience.

A key implementation challenge is the fragmentation of governance structures across multiple levels of government. While the Ministry of Land, Infrastructure and Transport (MOLIT) plays a central coordinating role, other agencies—including the Ministry of Science and ICT, the Ministry of Environment, and local governments—often pursue overlapping or unaligned agendas. This institutional siloing leads to inefficiencies in resource allocation, policy enforcement, and performance monitoring [3].

Local governments, which are expected to serve as primary actors in deploying smart city initiatives, frequently lack the technical capacity or financial autonomy to fulfill their responsibilities. This has created a reliance on central government funding and top-down directives, which can undermine local ownership and limit context-sensitive innovation. In some cases, conflicting regulatory interpretations between national and municipal authorities have stalled progress on key technologies such as autonomous mobility or data-sharing platforms.

Furthermore, citizen participation mechanisms, while expanding, remain underutilized or symbolic in many cities. Although pilot projects like Sejong have made strides in participatory governance, scaling these practices nationwide requires more robust legal frameworks, inclusive platforms, and civic capacity-building efforts.

Data is often referred to as the “lifeblood” of smart cities, yet achieving seamless data integration remains a formidable challenge in South Korea’s urban innovation agenda. Although urban data platforms (UDPs) have been developed in several cities, these systems are frequently fragmented, non-interoperable, or constrained by proprietary standards imposed by vendors [5, 7].

One major issue is the lack of a unified national framework for data architecture. While the Smart City Act encourages open data and platform integration, implementation varies widely across regions. This inconsistency leads to inefficiencies in data use, duplication of technological investments, and difficulties in benchmarking and evaluation.

Privacy and data security further complicate integration efforts. While Korea has relatively strong digital infrastructure, public trust in government data use remains uneven, particularly following data breaches or cyberattacks. Without transparent governance mechanisms and clear accountability structures, citizen engagement with smart services may remain superficial.

To address these issues, some cities have begun experimenting with federated data models and decentralized governance structures. However, these efforts are still in nascent stages and require further regulatory clarity and stakeholder alignment to be sustainable at scale.

Public-private partnerships (PPPs) are widely recognized as essential for financing and implementing smart city solutions, especially in technology deployment,

infrastructure management, and service delivery. In South Korea, major firms such as LG CNS, Samsung SDS, and KT Corporation have played active roles in national pilot projects. However, these partnerships are not without complications.

One persistent issue is the imbalance of power and risk between public institutions and private entities. In many cases, public agencies bear the regulatory and political risks, while private partners retain proprietary control over critical data and platforms. This dynamic can lead to vendor lock-in, reduced public accountability, and constrained flexibility for municipal innovation [8, 9].

Moreover, the incentive structures for private companies are often misaligned with public service objectives. While firms are motivated by return on investment, governments prioritize inclusiveness, long-term sustainability, and citizen trust—objectives that are not always compatible with short-term commercial strategies. Establishing fair and transparent procurement processes, standardizing evaluation criteria, and ensuring mutual accountability are essential steps toward more equitable partnerships.

Additionally, small and medium-sized enterprises (SMEs) often face barriers to entry in smart city markets, which are dominated by large corporations. This concentration limits the diversity of solutions and undermines innovation ecosystems at the local level. Some cities have sought to address this by creating innovation sandboxes and challenge programs, but such initiatives require stronger institutional support to be effective.

Overcoming these challenges requires a shift toward more adaptive and inclusive implementation models. Governance must evolve to enable multi-level coordination, with clearly defined roles, shared digital standards, and participatory oversight. Interoperable data platforms and privacy-preserving technologies should be supported through national guidelines and public investment. PPP frameworks need to move beyond transactional arrangements and toward long-term strategic alliances grounded in mutual benefit and public value.

Ultimately, the success of South Korea's smart city vision hinges not just on technological sophistication but on its capacity to build institutional resilience, foster trust, and align innovation with the broader goals of equity, sustainability, and democratic governance. These lessons are equally vital for emerging economies seeking to build their own smart urban futures.

7. Comparative reflections: Emerging economies

South Korea's smart city experience presents a unique policy model that blends high technological sophistication with centralized coordination and citizen-focused planning. For many emerging economies, this model offers both inspiration and practical guidance. Countries in regions such as Southeast Asia, the Middle East, and Latin America are increasingly investing in smart city strategies to address challenges like rapid urbanization, resource constraints, and governance inefficiencies. However, replicating Korea's model requires careful contextual adaptation, as the institutional, cultural, and economic environments in these countries differ significantly from those of South Korea.

Many of the challenges that South Korea faced during its own rapid development, such as congestion, pollution, infrastructural gaps, and uneven public service delivery, are mirrored in contemporary emerging economies. This similarity increases the relevance of Korea's experience. For instance, ASEAN countries such as Vietnam, Indonesia, and Thailand are pursuing national smart city frameworks and have

established pilot zones with a strong emphasis on infrastructure modernization and digital service delivery.

South Korea's success in integrating national vision with local experimentation through pilot projects like Sejong and Busan provides a useful roadmap. The top-down coordination by ministries such as MOLIT and the establishment of dedicated legal frameworks (e.g., Smart City Act [1]) show how policy alignment and resource centralization can accelerate smart city deployment. Countries like Saudi Arabia (e.g., NEOM project) and the UAE (e.g., Dubai Smart City) have also adopted state-led approaches and could benefit from Korea's experience in institutional design, regulatory frameworks, and data governance [10, 11].

In addition, Korea's emphasis on public-private partnerships (PPPs), citizen co-creation, and open data standards may offer valuable mechanisms for countries where digital ecosystems are still emerging but rapidly expanding. Korea's innovation sandboxes and challenge programs also serve as flexible platforms for involving local startups and SMEs in smart city development—a model that aligns well with entrepreneurship-based growth strategies in countries like Malaysia or the Philippines.

Despite these opportunities, there are substantial barriers to direct replication. Korea's model is underpinned by specific institutional preconditions: high levels of digital literacy, universal broadband access, strong public sector capacity, and a relatively centralized political system. In contrast, many emerging economies have fragmented governance, insufficient funding mechanisms, and regulatory uncertainty that hinder cross-sectoral coordination. For example, smart city initiatives in parts of Africa and South Asia often suffer from project silos, lack of inter-ministerial collaboration, and inconsistent political will.

Furthermore, Korea's smart cities benefit from a culture of civic compliance and data-sharing that may not easily transfer to societies with strong concerns about privacy, government overreach, or digital inequality. The high trust in government and technology that enables Korean citizens to engage with digital governance platforms may be more difficult to foster in contexts where public institutions face legitimacy issues.

Moreover, technological leapfrogging is often cited as an advantage for emerging markets, it may come with its own risks, especially when local capacities for maintenance, data analysis, and cyber-resilience are underdeveloped. Without adequate capacity-building, importing high-tech solutions may lead to dependence on foreign vendors and unsustainable infrastructures.

For the Korean model to be effectively adapted to emerging economies, several strategic principles should be considered:

- **Localization over replication:** Korean smart city tools and policies should be treated as adaptable frameworks rather than fixed templates. Local governments must be empowered to tailor solutions to their urban contexts, institutional capacity, and sociopolitical dynamics.
- **Capacity-building and knowledge transfer:** Korea can play a leading role in south-south cooperation through training programs, joint research, and government-to-government exchanges. Institutions like the Korea Land and Housing Corporation (LH) and the Korea Agency for Infrastructure Technology Advancement (KAIA) already support such initiatives.
- **Phased implementation:** Rather than pursuing fully integrated smart cities from the outset, emerging economies may benefit from modular, phased approaches

that allow for learning and adjustment. Pilot programs can evolve into broader frameworks only after proof of concept is demonstrated.

- **Citizen-centered innovation:** Participatory governance and inclusion of underserved communities should be central to any smart city strategy. This is particularly crucial in countries with high levels of informal settlements or digital divides.
- **Open standards and interoperability:** Korea's experience underscores the value of interoperable platforms and shared digital infrastructure. This lesson is especially important for emerging economies aiming to prevent vendor lock-in and support long-term innovation ecosystems.

South Korea's smart city journey offers compelling lessons for emerging economies, but it is not a one-size-fits-all model. Its greatest value lies not in its replication but in its adaptable components: strong institutional alignment, long-term strategic planning, experimentation through pilot projects, and multi-actor collaboration. Emerging economies that are able to integrate these principles into their own unique governance and development trajectories may find in Korea's model not only a blueprint, but a partner in building resilient, inclusive, and intelligent urban futures.

8. Policy recommendations

South Korea's experience in developing smart cities offers a compelling body of practice that can inform both domestic policy refinement and international strategy transfer. However, translating this experience into sustainable outcomes, particularly in emerging economies, requires not only understanding what has worked but also how it can be adapted, scaled, and institutionalized. Based on the preceding analysis, this chapter outlines key policy recommendations in three strategic areas: decentralized innovation, regulatory reform, and citizen-centered governance.

One of the limitations of South Korea's smart city governance model is the over-reliance on central planning. While this has allowed for efficient resource mobilization and policy alignment, it can also suppress localized innovation, particularly when regional governments lack autonomy or capacity. To foster innovation that is both scalable and context-sensitive, national governments, whether in Korea or abroad, should promote decentralized experimentation.

This involves empowering local governments to initiate pilot projects tailored to their unique social, environmental, and economic conditions. National ministries can provide enabling frameworks, seed funding, and technical guidance, but the design and implementation should be locally led. The Smart City Challenge Program in Korea offers a promising example: it provided localities with the opportunity to partner with startups and test urban technologies at smaller scales before broader rollout [12].

Furthermore, institutionalizing local innovation labs, urban R&D consortia, and university-government partnerships can enhance regional capacity for smart city planning. In emerging economies, such mechanisms can help build endogenous problem-solving capabilities and reduce dependency on imported turnkey solutions.

Smart cities operate at the intersection of multiple regulatory domains, including data governance, digital infrastructure, transportation, housing, and environmental policy. A common bottleneck in both Korea and emerging economies is the lack of coherent regulatory frameworks that support cross-sectoral innovation.

Governments should adopt adaptive regulation, which allows for real-time policy updates in response to technological change. Regulatory sandboxes—where new technologies can be tested under controlled conditions—should be expanded and coupled with structured evaluation mechanisms. For example, Korea’s regulation-free zones for autonomous vehicles and telemedicine have enabled rapid prototyping while managing risk [5, 10].

Moreover, interoperability standards should be mandated for data platforms, IoT infrastructure, and public procurement processes. This ensures that different systems can communicate and evolve without vendor lock-in, reducing costs and increasing resilience. Legal frameworks must also balance data security with open access, and clarify responsibilities for cybersecurity breaches or algorithmic bias in public services.

For emerging economies, prioritizing clear digital rights, capacity-building in regulatory institutions, and harmonization of smart city policies across ministries will be crucial for sustaining innovation.

Technological sophistication alone does not make a city “smart.” Without meaningful citizen participation, smart cities risk becoming technocratic projects that deepen social inequality. Korea’s shift from infrastructure-heavy U-Cities to participatory smart cities such as Sejong underscores this point.

Governments should institutionalize citizen engagement frameworks that go beyond consultation and enable co-creation. This includes establishing digital platforms for participatory budgeting, urban planning feedback, and service performance monitoring. For example, in Sejong, residents use mobile apps to vote on neighborhood-level projects and submit real-time reports on public issues [6, 13].

Digital inclusion strategies are also essential. This involves investing in digital literacy education, ensuring access to internet infrastructure, and designing inclusive interfaces for people with disabilities, the elderly, and marginalized populations. Social innovation funds can be deployed to support civic tech startups that work on digital democracy and community-driven platforms.

In international contexts, particularly in the Global South, the success of citizen participation models depends on trust in public institutions, cultural norms of engagement, and safeguards against digital exclusion. Policymakers must therefore embed participation into smart city design from the outset, rather than treating it as a downstream addition.

In summary, smart city development must move beyond technology deployment toward institutional transformation. Governments at all levels should:

- Enable decentralized innovation ecosystems by empowering local governments and stakeholders.
- Create adaptive and coherent regulatory environments that keep pace with innovation.
- Institutionalize citizen participation through robust legal mandates and inclusive design.

South Korea’s case demonstrates that success in these areas is not only possible but necessary for long-term resilience, democratic legitimacy, and inclusive development. By adopting these policy directions, other countries can transition from fragmented digital infrastructure toward truly smart, equitable, and sustainable urban futures.

9. Conclusion

South Korea's journey in developing smart cities offers a distinctive model that integrates technological innovation, centralized policy coordination, and increasing citizen participation. Through a strategic combination of national vision and local experimentation, Korea has transformed once-infrastructure-centric U-City projects into participatory, data-driven, and environmentally conscious urban ecosystems. The national pilot projects in Sejong and Busan exemplify how different cities can pursue unique innovation pathways while remaining aligned with broader policy goals.

The lessons emerging from Korea's experience are manifold. First, smart city development requires a clear and enabling institutional framework. Korean Smart City Act [1] established legal foundations that supported inter-ministerial coordination, funding mechanisms, and regulatory flexibility. Second, pilot projects are critical as living laboratories that allow for iterative innovation, community engagement, and technological risk mitigation. Third, public-private partnerships (PPPs) and local entrepreneurship play a central role in mobilizing expertise, fostering innovation, and sustaining operational models. However, careful attention must be paid to issues of data ownership, public accountability, and inclusive access to technology.

Equally important are the challenges Korea continues to face: fragmented governance among ministries, uneven data integration across cities, limited involvement of smaller firms, and varying levels of citizen engagement across localities. These obstacles reflect the broader reality that smart city development is as much a sociopolitical endeavor as it is a technological one. As such, future progress depends on the country's ability to build institutional resilience, strengthen trust, and embed equity into digital urban governance.

For emerging economies, Korea's model provides guiding principles rather than a replicable blueprint. Countries across Southeast Asia, the Middle East, and Africa can draw from Korea's experience by adapting its flexible elements—such as participatory frameworks, urban data platforms, and challenge-driven innovation—into their own policy and governance contexts. However, success will depend on local capacity-building, contextual adaptation, and inclusive planning processes.

Looking ahead, the future of smart cities—both in Korea and globally—lies in moving beyond fragmented digital infrastructure toward integrated, citizen-centered urban systems. Key areas for advancement include climate-smart planning, ethical AI integration, urban digital twins for scenario forecasting, and cross-border smart city cooperation. South Korea, with its evolving ecosystem and policy maturity, is well-positioned not only to deepen its own smart city transformation but also to contribute to global knowledge-sharing networks.

In conclusion, the Korean experience teaches us that the smart city of the future is not just one that connects devices, but one that connects people, institutions, and visions for a more sustainable and inclusive urban future.

Conflict of interest

The authors declare no conflict of interest.

Author details

Jae Eun You

The Korea Institute of Public Affairs, Seoul National University, South Korea

*Address all correspondence to: jaeyou@snu.ac.kr

IntechOpen

© 2025 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. 

References

- [1] Korean Smart City Act. Act on the Creation of Smart Cities and Industry Promotion, Etc. Sejong: National Legal Information Center, Ministry of Legislation; 2024. Available from: <https://www.law.go.kr/lsInfoP.do?lsId=010730#0000>
- [2] Ismagilova E, Hughes L, Dwivedi YK, Raman KR. Smart cities: Advances in research—An information systems perspective. *International Journal of Information Management*. 2019;47:88-100
- [3] Lee TJ, Cho M. Evaluation and Policy Recommendation on Smart City Business in Korea. Sejong: Korea Development Institute; 2020. pp. 2020-2008
- [4] Javed AR, Shahzad F, ur Rehman S, Zikria YB, Razzak I, Jalil Z, et al. Future smart cities: Requirements, emerging technologies, applications, challenges, and future aspects. *Cities*. 2022;129:103794
- [5] Kim JS, Seo BK, Chang HW. Analysis and customization of Busan Smart City. Busan: Busan Metropolitan Council; 2023. pp. 2023-2004
- [6] Choo M, Choi YW, Yoon H, Bae SB, Yoon DK. Citizen engagement in smart city planning: The case of living labs in South Korea. *Urban Planning*. 2023;8(2):32-43
- [7] Lim Y, Edelenbos J, Gianoli A. Dynamics in the governance of smart cities: Insights from South Korean smart cities. *International Journal of Urban Sciences*. 2023;27(suppl. 1):183-205
- [8] Yoo Y. Toward sustainable governance: Strategic analysis of the smart city Seoul portal in Korea. *Sustainability*. 2021;13(11):5886
- [9] Alizadeh H, Sharifi A. Toward a societal smart city: Clarifying the social justice dimension of smart cities. *Sustainable Cities and Society*. 2023;95:104612
- [10] Joo YM. Developmentalist smart cities? The cases of Singapore and Seoul. *International Journal of Urban Sciences*. 2023;27(suppl. 1):164-182
- [11] Njoh AJ. *Urban Governance in Southeast Asia*. Heidelberg: Springer Nature; 2024
- [12] Park SH, Bang Shin H, Soo Kang H. *Exporting Urban Korea?*. Milton Park: Routledge, Taylor & Francis; 2021
- [13] Jang SG, Gim THT. Considerations for encouraging citizen participation by information-disadvantaged groups in smart cities. *Sustainable Cities and Society*. 2022;76:103437

Missed Potentials of Recycling in Urban Planning: Case of East African Cities

Ogutu Florence and Kathambi Bessy

Abstract

Integrating recycling into urban planning is essential for smart cities in East Africa, offering significant benefits such as waste reduction, economic growth, and sustainability. Efficient recycling systems can reduce landfill waste and conserve natural resources. The establishment of recycling facilities creates job opportunities and supports circular economic initiatives. Effective recycling practices lower greenhouse gas emissions and protect biodiversity. Engaging communities through awareness campaigns and leveraging technology strengthens recycling efforts. Innovative technologies, such as smart bins and data analytics, enhance waste management processes. Collaborating with private companies promotes innovative recycling solutions and provides funding opportunities. Recycling boosts urban resilience by reducing dependence on finite resources and encouraging sustainable infrastructure. However, challenges like limited infrastructure, cultural attitudes, and financial constraints must be tackled. By utilizing technology, engaging communities, and forming partnerships, East African cities can transform waste management into a chance for innovation and a better quality of life.

Keywords: recycling, missed potentials, urban planning, East African cities, collaborations

1. Introduction

Globally, solid waste generation is increasing at an unprecedented rate due to rapid population growth, urbanization, and consumption behaviors [1]. It is projected that waste generation will rise to 3.40 billion tons by 2050, more than double the population growth rate. In developing countries, particularly in East Africa, waste generation is accelerating due to population growth, rapid urbanization, and lifestyle changes that lead to high resource consumption [2, 3].

Solid waste management (SWM) encompasses the overall management of waste generation, including processing, treatment, recovery, disposal in landfills, indiscriminate dumping, open burning, and recycling where appropriate [4, 5]. Waste management poses significant challenges in many developing countries, where governance structures are overwhelmed. The collection rate in urban areas is low at 44%, and drops significantly to 26% outside urban areas, negatively impacting public health and the environment [6–8].

To achieve sustainable waste management in Africa, including East Africa, comprehensive measures and policies must be implemented to address existing challenges, particularly in waste management infrastructure. One significant gap affecting the continent is the recognition of the full potential of recycling within urban planning and the economic and environmental benefits associated with it [2, 5, 9].

Recycling involves collecting and converting waste into reusable products, transforming waste into a resource, and promoting a zero-waste culture [5]. The benefits of recycling include reduced pollution and global warming, job creation, and decreased waste sent to landfills and incineration [1, 10].

In East Africa, recycling is a multifaceted and developing sector. Cities face increased waste generation: Kenya's waste generation has increased by 60%, Tanzania's by 70%, Uganda's by 60%, and Rwanda's by 63% [10–12]. This increase is driven by urbanization, population growth, rising purchasing power, and changing consumption habits, including greater use of packaged items and electronic devices. Additionally, there is a lack of environmental ethics, values, and stewardship, which leads to indiscriminate waste disposal [5, 6, 10].

Despite the rise in waste generation, recycling rates in East Africa are low, with only 4% of waste recycled and less than 10% of plastics being recycled. Recycling efforts are often conducted informally by waste pickers who rely on this activity for their livelihoods. Organic waste, which constitutes 90% of the waste generated, offers opportunities for composting, biogas production, and animal feed, highlighting the missed potential in recycling [5, 11].

Challenges faced by East African cities in recycling include limited formal recycling infrastructure, inefficient collection systems, inadequate sorting facilities, insufficient processing plants, hurdles within the informal sector, poor waste segregation, weak policy implementation and enforcement, and limited financial and human resources [5, 8, 11].

However, there is hope. East African Countries are increasingly integrating recycling into their urban planning, led by private sector initiatives and supported by international organizations and proactive policy and regulatory frameworks. Rwanda and Kenya have banned single-use plastics to combat plastic pollution. Community-based initiatives, technological advancements, and improvements in waste management infrastructure also contribute to this positive trend [3, 13, 14].

2. Recycling in East Africa, case of Kenya and Rwanda

2.1 Recycling in Kenya

Waste management remains a significant issue in Kenya due to the increased waste generated in rapidly developing urban centers, with local authorities struggling to keep up. For instance, Nairobi produces 2400 tons of waste daily, of which only 38% is collected and less than 10% is recycled [6, 10, 15].

Recycling in Kenya is growing, driven by Vision 2030, which aims for Kenya to become an industrialized state. Effective and sustainable waste management systems are essential for this goal. An assessment of the waste management policy landscape, based on EMCA (1999) and amended in 2015, led to the Sustainable Waste Management Act, 2022. This act introduced the extended producer responsibility (EPR) and the 7R concept: reducing, rethinking, refusing, recycling, reusing, repairing, and refilling. The act provides a comprehensive framework for waste

management and promotes recycling through EPR principles and the development of material recovery facilities (MRFs) [16–18].

Kenya has made progress in recycling within the agricultural sector, as 90% of waste is organic. Other wastes includes plastics, recycling rate low, at 5% and e-waste, an untapped potential [9, 10]. Various innovative initiatives in recycling are being carried out by informal waste pickers, community-based organizations (CBOs), the private sector, international partners, and the government. These efforts focus on sustainable waste management [10, 19].

Several key players are involved in recycling organic waste in Kenya, including CBOs, the private sector, NGOs, informal waste pickers, and government agencies. Organic waste is recycled through various initiatives such as biogas production, fertilizers, and cooking fuel. These initiatives aim to create wealth, generate employment, clean the environment, and meet sustainable development goals 7 and 11 (SDG) [7, 20].

Examples include the recycling of sugarcane waste into clean energy pellets, which helps reduce plastic waste and deforestation, the first and only A evaluated cookstove project, 98% cleaner, 70% less biomass, and 50% inexpensive. Eco Banana Limited, a student- and youth-led social enterprise, transforms banana trucks into menstrual pads, a high-demand product and the first 100% organic sanitary pads in Kenya [5]. Additionally, Mananasi Fiber Ltd. recycles pineapple waste into baskets, sanitary ware, baby pampers, clothes, and shoes. Water hyacinth, an invasive plant, is recycled to produce animal feed, craft materials, compost fertilizer, paper, and building materials (**Figures 1–3**) [20].

Recycling of biogas, where organic waste is converted into renewable energy at Gorge Energy Farm in Naivasha, a large-scale biogas plant. It produces 2 MW of power, serving 5000–6000 households, and generates fertilizers as a by-product. The plant sells 5 megawatts of power to the national grid [10, 22]. Also, recycling organic waste into Insect feed, using black fly soldier technology for organic fertilizers and biofuel (**Figure 4**) [22, 24].



Figure 1.
Clean cookstoves and energy pellets (made from sugar waste) have met the World Health Organization (WHO) definition for a clean cook stove, as illustrated in the above images. Source: <http://ecosafi.com>. <https://www.globeneswire.com/news>



Figure 2.
The pictures above reveal how banana truck waste is recycled into sanitary pads. Source: Ref. [21].



Figure 3.
The image above shows a Pineapple waste processing plant. Source: <https://www.talkafric.co.ke/circular-economy>

CBOs and the private sector significantly contribute to addressing waste management issues. Taka Solutions recycles 95% of the waste they collect by composting it into fertilizer, improving soil fertility, water retention, and agricultural productivity [25]. Other examples include Kibuye Waste Management CBO, Korogocho Food Waste Management, and Community Youth Action for Development, which recycle waste into organic fertilizer and biomass briquettes (**Figure 5**).

Organic Fields Limited, a private initiative, recycles food waste and animal waste into high-quality organic fertilizer, supporting sustainable agriculture and promoting



The Gorge Farm Energy Park, located in Naivasha, produces 2MW of electricity, which is more than enough to cultivate its 706 hectares of vegetables and flowers.

Figure 4.
The Gorge farm, organic waste recycled into renewable energy as shown above. Source: Ref. [23].

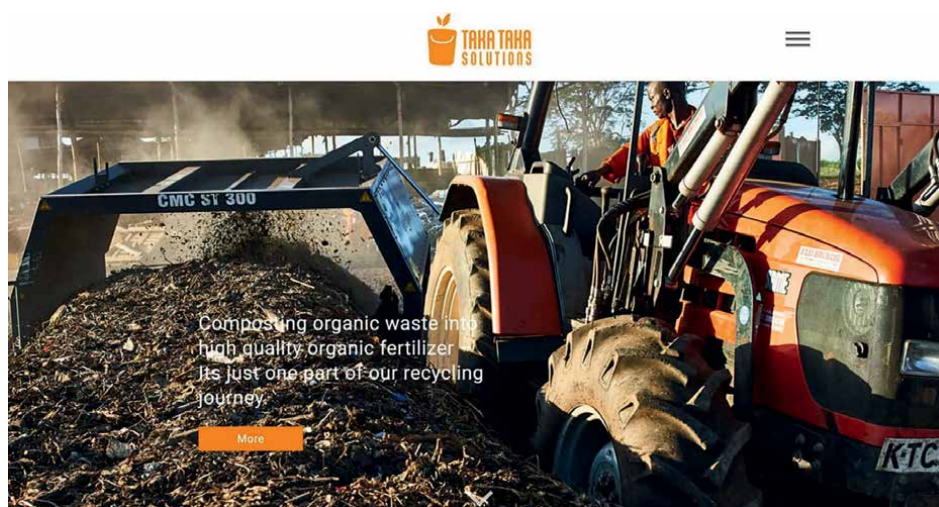


Figure 5.
Taka Solutions, the image above shows a tractor working on organic waste organic waste. Source: UNFCCC [https://unfccc.int > climate> - action>activity-database](https://unfccc.int>climate>-action>activity-database).

circularity and community empowerment [10, 24]. Additionally, there is composting within the dairy sector through private-public partnerships, recycling manure from animal waste to promote sustainability and resilience amidst climate change. Additionally, Keekonyokie slaughterhouse, in Kiserian North, converts animal waste to biogas (**Figure 6**) [14, 24, 26].

Despite the progress in organic recycling in Kenya, challenges remain. These include infrastructure deficits, inadequate waste collection and segregation,



Figure 6.

Organic Fields Limited, the image above shows healthy green agricultural fields using organic fertilizer. Source: <https://www.organicfields.o.ke/>, Vc4A (Ventures for Africa) <https://vc4a.com/ventures/organic-fields-ltd/>.

uncollected waste, limited recycling infrastructure, financial constraints, issues faced by waste pickers, policy implementation and enforcement difficulties, and public attitudes [9, 14, 24]. However, the future of recycling appears promising due to increasing policy support, innovative initiatives, and the benefits derived from these efforts, laying a strong foundation for continued progress.

2.2 Recycling in Rwanda

Rwanda is a circular economy leader in Africa in waste management and recycling, where the environment and climate change are entrenched in the policies, regulations, strategies, and agendas, with its vision aiming at a zero-waste culture by 2050, entrenched in the National Circular Economy Action Plan and Roadmap.

Additionally, Rwanda has the Green Fund (FONERWA), a climate change investment fund in Africa for transformative innovative projects, boosting recycling [11, 12, 27].

Rwanda has done well in waste management in Africa, especially in the sector of recycling, aiming to reach a recycling rate of 50% and Rwanda is a model country. Notwithstanding, Rwanda faces challenges and barriers to attaining its goals. There are policy implementation and enforcement breaches, inadequate waste management infrastructure, low public participation, especially sorting at the household level, low financial capacity, and negative public attitude on waste management and integrating the informal sector into the formal waste management infrastructure has not succeeded [12, 19].

Despite the challenges, Rwanda has made advances in waste management in Africa, recycling sector created more jobs for the youth, it is a model Nation and its proactive stance in environmental protection and sustainable waste management and recycling, the future is greener, cleaner and sustainable city in Africa, aligned with UN sustainable Development Goals (SDGs), goal 11 [24, 28].

2.3 Recycling scenario in Uganda

Uganda grapples with significant waste management challenges due to urbanization, population growth, and changing consumption patterns [29, 30]. Despite

producing around 600 metric tonnes of plastic waste daily, only about 40% is properly disposed of in Kampala [31, 32]. Uncollected waste often ends up in open dumps, waterways, and informal sites, leading to environmental and health hazards [29, 33].

A major issue is the lack of waste segregation at the source, complicating recycling efforts. The current recycling capacity for plastics stands at around 3%. The informal waste picker sector plays a crucial but largely unregulated role in collecting and sorting recyclables under poor working conditions, as illustrated in **Figure 7** [34, 35].

Uganda has regulations like the National Environment (Waste Management) Regulations, 2020, which aim to manage waste through environmentally friendly practices [36]. However, challenges such as inadequate waste collection, poor segregation practices, limited recycling infrastructure, and a lack of financial incentives hinder progress [31]. E-waste management is also an emerging concern, with nascent systems in place [29, 37].

Several initiatives are contributing to a circular economy:

- *Lira recycling center*: Collected over 150 tonnes of plastic waste in 3 years, providing livelihoods for over 500 waste collectors [33].
- *Youth-led initiatives*: City Pioneers and Dream Achievers recycle organic waste and plastic bottles into useful products.
- *EcoPick (U) Ltd*: Provides waste management services to transform Mbale into a green city.
- *Kyaffe coffee briquette*: Produces eco-friendly briquettes from coffee husks.

For a robust circular economy, Uganda needs better recycling infrastructure, improved waste segregation, increased public awareness, and stronger collaboration among stakeholders. The “National Strategy for Promoting Plastics Circularity



Figure 7.
Recycling of plastics and other materials in Uganda [31].

in Uganda 2023-2028” emphasizes reuse, recycling, and promoting biodegradable alternatives to tackle plastic pollution [29, 36].

2.4 Recycling scenario in Tanzania

Tanzania, akin to many developing nations, faces a significant challenge in managing its rapidly increasing solid waste, particularly in burgeoning urban centers in cities such as Dar es Salaam [38, 39]. The volume of waste generated annually is substantial, estimated between 14.4 and 20.7 million tonnes, with up to 70% being recyclable; however, the actual recycling rate remains remarkably low, typically between 5 and 10% [3, 40]. This scenario indicates nascent but growing efforts, significant contributions from the informal sector, and a critical need for enhanced infrastructure and systemic change [41, 42].

The recycling landscape in Tanzania can be characterized by several key aspects:

Informal sector dominance: The backbone of recycling in Tanzania is undoubtedly the informal waste sector. Waste pickers, operating at the grassroots level, play a crucial role in collecting, sorting, and trading recyclable materials. They are responsible for diverting a substantial amount of waste from landfills, with plastics being the most collected material [25, 43]. Despite their vital contribution, waste pickers often face challenging working conditions and receive low compensation, highlighting a need for formalization and improved income opportunities [25, 40]. Their adaptability and ability to respond quickly to demand make them an indispensable part of the current system [41, 44].

Nascent formal sector and growing initiatives: While the informal sector leads, the formal recycling sector is gradually emerging, primarily focused on plastics, paper, and metals. Efforts are underway to establish recycling facilities and improve overall waste management infrastructure. For instance, the *Plastic Recycling and Youth Empowerment (PREYO) TZ* is a community-based organization actively collecting and recycling PET, HDPE, and PP plastics, simultaneously providing training and support for waste pickers explicated in **Figure 8** [41, 43, 45].

Policy and strategic push: The Tanzanian government aims to enhance recycling efforts. The Vice President’s Office has developed the 2025–2030 waste management strategy, intending to collect and recycle 12.5 million tonnes of plastic waste annually [46, 47]. Additionally, the government has established guidelines on waste recycling to promote investment and improve waste management in urban areas [39, 43, 47].

The recycling situation in Tanzania looks like this:

Low collection rates: A significant portion of waste generated, particularly in urban areas, remains uncollected. Estimates suggest that less than 35–50% of the generated waste is collected, with the remainder often openly dumped, burned, or ending up in waterways [41, 44]. In Dar es Salaam, roughly a quarter of the 4500 tonnes produced daily reaches the dumpsite [40].

Dominance of dumpsites: Most municipal solid waste (MSW) is disposed of in open and poorly operated dumpsites. While some municipalities (e.g., Arusha, Tanga, and Mwanza) have improved landfills, these are still limited [46].

Low recycling rate: Despite a significant portion of waste being recyclable (approximately 70%), the actual recycling rate remains very low, estimated between 5 and 10%. This recyclable waste includes plastics, paper, metals, electronic waste, and used oil [41, 42].

Photos: Plastic recycling enterprise



Figure 8.
Small recycling station in Tanzania [25].

Composition of waste: Major waste-producing areas indicate that garden waste, food remains, wood, and electronic waste constitute a large portion of solid waste [14, 24]. Biodegradable waste is particularly challenging to manage due to its perishable nature and environmental impact when leaching from landfills [45, 47].

2.5 Challenges to recycling in Tanzania

Inadequate infrastructure: Many regions lack sufficient infrastructure for waste collection, transportation, and disposal, including modern recycling facilities and sanitary landfills [41].

Lack of awareness and education: Low public awareness about proper waste disposal and recycling practices contributes to widespread mismanagement. The “3 Rs” (Reduce, Reuse, Recycle) concept is not widely known [48, 49].

Weak regulatory enforcement: Insufficient enforcement of regulations and monitoring mechanisms undermines efforts to promote compliance with waste management standards [40, 43, 50].

Financing issues: Inadequate financing, disbursement delays for service providers, and insufficient collection of waste charges hamper effective waste management [46].

Population growth and urbanization: Rapid urban expansion outpaces the capacity of existing infrastructure, exacerbating waste management challenges [39, 47].

Complex informal sector integration: While crucial, integrating the informal waste sector into formal systems faces challenges related to organization, business management, and political will [25, 46, 51].

The recycling scenario in Tanzania presents a dynamic landscape of challenges and emerging opportunities. Significant hurdles remain in infrastructure, public awareness,

and policy enforcement. However, the commitment to a circular economy, combined with the vital roles of informal and community-based initiatives, offers a promising path toward sustainable waste management. Technological innovations provide new avenues for improvement. Digital platforms like *Afia Solutions* and *TakaBilaStress* are emerging in Dar es Salaam to connect waste producers with collectors and recyclers, streamline operations, and collect data for better decision-making [46]. Increased focus on organic waste composting, as seen with Nipe Fagio's *Mawasiliano Organic Composting Facility*, offers multiple benefits: emission reduction, climate resilience, and livelihood empowerment [52].

Leveraging digital solutions, formalizing and supporting waste pickers, and scaling up composting efforts represent key opportunities to transition toward a more circular and sustainable waste management system, which is crucial for both environmental protection and socio-economic development.

3. Missed potential of recycling in agriculture and industry in East Africa

East Africa is facing a growing waste management problem due to rapid urbanization and population growth that exceed the capacity of the current infrastructure and systems. A large volume of waste, especially organic and plastic, is produced in the region, but recycling rates are very low. This situation is a major missed opportunity to turn waste from a burden into a useful resource, which could benefit the environment, economy, and society.

3.1 Agricultural sector

Various innovative initiatives are contributing to the circular economy in agri-business:

3.1.1 Circular food systems project

Initiatives spearheaded by private-public partnership in collaboration with the international organizations and government support to accelerate recycling and avert hunger, transform the food system into circularity, supporting small and medium enterprises (SMEs) financially to embrace business models where they are trained to apply the 3R concept; reduce, reuse and recycle, food processing skills and innovative initiatives [12, 24, 53].

3.1.2 Organic waste valorization

Rwanda 75% of its waste is organic, the government unlocking this potential through composting, waste is recycled into animal feeds, compost (manure) biogas production through using biogas digesters and vermicomposting, where black soldier fly technology is used (BSF) Also, agricultural waste is recycled into high-quality compost, recovers soil condition, reduces reliance on imported fertilizers and enhanced agricultural production (**Figure 9**) [12, 54].

3.1.3 The inauguration of the first municipal waste valorization facilities at the Ndubi dumpsite in Kigali

It has a truck weighbridge to confirm the quantity of waste received daily, which is vital for effective and sustainable waste management. It helps to mitigate emissions from



Figure 9.
Organic waste valorization site as shown above. Source: Ministry of Environment www.environment.gov.rw,
COPED (company for protection of environment and development) www.copedgroup.rw.

the waste and creates employment [54, 55]. Has the capacity to treat five tons of waste daily and has processed over 165 tons into compost since its foundation, making it the first waste treatment and processing infrastructure facility in East Africa. There is increased public-private partnership in waste management, accelerating recycling (**Figure 10**) [54].

3.1.4 Environmental education

Rwanda has integrated environmental education into its education system, in which source separation and sustainable waste management practices are compulsory to create public awareness and participation, boosting recycling [11, 12].

3.1.5 Smart cities initiative

Initiative by the government to promote circularity using technology in innovation [11].

3.1.6 Green growth strategy

The government's effort to enhance sustainable development and environmental protection through reduced taxes for investors in the waste management sector [54].

3.2 Industry

East Africa faces a complex issue in waste management: an escalating waste crisis coincides with significant untapped recycling potential, particularly within its



The sorting and waste recycling at Nduba dumpsite was funded by the Ministry of Environment, Climate, and Biodiversity of the Grand Duchy of Luxembourg. The project was implemented in partnership with the Global Green Growth Institute.

Figure 10.

Nduba dumpsite recycling plant, as shown above. Source: GGGI-Global Green Growth Institute gggi.org [54].

industrial sectors. The region struggles with low collection rates, overfilled dumpsites, and limited public awareness regarding waste segregation, while industries frequently overlook the substantial economic, environmental, and social advantages that a robust industrial recycling ecosystem could offer.

Outlined below are some of the key missed opportunities in industries related to waste management and recycling in East Africa:

3.2.1 Missed economic opportunities and value chains

Loss of raw materials: Industries often discard valuable materials that could be reintegrated into their own production cycles or sold as raw materials to other industries. This includes considerable volumes of textile waste (e.g., Kenya's garment manufacturers generate approximately 400,000 tons of cotton waste annually, which often ends up in dumps), plastic offcuts, metal scraps, glass cullet, paper and cardboard packaging, and organic waste [14, 24]. This represents a direct economic loss concerning virgin material purchases.

Lack of industrial symbiosis: There is a significant missed opportunity in the lack of "industrial symbiosis" – where the waste or by-product of one industry becomes a valuable input for another. For instance, excess heat from one factory could power another, or spent grains from a brewery could be used as animal feed or for biogas production. Despite East Africa's emerging industrial landscape being well-positioned to develop these interconnected systems, coordination and infrastructure are often lacking.

Underdeveloped secondary markets: Markets for recycled materials are frequently fragmented and underdeveloped, making it difficult for industries to find reliable

buyers for their segregated waste streams, thereby discouraging in-house recycling efforts. Investment in processing facilities (e.g., plastic pelletizers, paper pulping plants, and metal smelters) and clear market linkages are essential.

Job creation: A flourishing industrial recycling sector would create numerous jobs across the value chain—from collection and sorting to processing, manufacturing new products, and logistics. This potential for green job creation, particularly for youth and women in the informal sector, remains largely unfulfilled [28, 56]. The African Circular Economy Alliance (ACEA) estimates that the circular economy could create over 11 million jobs in Africa by 2030 [56].

3.2.2 Environmental and climate mitigation potential

Reduced landfill burden: Industrial waste contributes significantly to landfill volume, which can result in unsanitary conditions. Recycling helps reduce waste sent to landfills, thus extending their lifespan and minimizing environmental hazards such as leachate contamination and methane emissions.

Lower carbon footprint: Manufacturing with recycled materials generally requires less energy and produces fewer greenhouse gas emissions compared to using virgin raw materials. Industries have opportunities to lower their carbon footprint and support national climate goals. For example, textile recycling could potentially reduce emissions in the fashion industry [11, 28].

Resource conservation: Recycling preserves finite natural resources like minerals, timber, and fossil fuels that would otherwise need to be extracted. East African industries, dependent on imported raw materials, could improve resource security by using recycled content.

Pollution reduction: Improper disposal of industrial waste pollutes air, water, and soil. Implementing recycling and proper waste management practices could mitigate this environmental degradation and protect ecosystems and public health.

3.2.3 Missed opportunities in policy and regulatory frameworks

Limited extended producer responsibility (EPR): Some East African Countries are introducing EPR schemes, such as packaging in Kenya, but their scope and enforcement are often insufficient. EPR places end-of-life product management responsibility on producers, encouraging them to make recyclable products and invest in recycling infrastructure [57]. Expanding EPR policies could drive more industrial recycling investments.

Lack of incentives for recycling: Financial incentives, such as tax breaks for using recycled materials or subsidies for recycling infrastructure, are often lacking. Without disincentives for waste generation, such as higher landfill fees, industries may find it more cost-effective to dispose of waste rather than recycle it.

Weak data collection and monitoring: Limited data on industrial waste streams prevent effective planning and investment in recycling infrastructure. Many industries do not accurately measure or report waste generation, hindering the identification of specific recycling opportunities.

3.2.4 Technological and innovation gaps

Limited investment in recycling technologies: Many East African industries lack access to or investment in advanced recycling technologies that are suitable for their specific

waste streams. This includes both simple sorting equipment and complex chemical recycling or waste-to-energy solutions.

Bridging the informal-formal divide: The large informal waste picker sector is important for current recycling efforts, but often lacks technology, safety equipment, and formal linkages to efficiently contribute to industrial recycling processes. Integrating informal waste pickers through cooperatives and partnerships could enhance recycling [28, 55].

Eco-design and circular business models: There are opportunities for industries to adopt eco-design principles, where products are designed to be durable, repairable, reusable, and recyclable. Circular business models can generate new revenue streams and competitive advantages [57].

East Africa's industrial waste management and recycling landscape presents numerous opportunities. Transitioning from a linear "take-make-dispose" model to a circular economy requires cooperation from governments, industries, and civil society. By investing in infrastructure, strengthening policies, fostering collaboration, and promoting innovation, East African nations can convert waste challenges into economic growth, job creation, and environmental sustainability benefits.

4. Conclusion

East African Countries have made some progress in recycling; however, one vital area where potential remains unexploited is the integration of recycling into urban planning, accelerating various missed opportunities for circular economy in terms of socio-economic development and environmental sustainability. Missed potentials, recycling given less priority, and waste systems have resulted in indiscriminate dumping in open fields, polluting waterways, impacting the environment, and human health. Additionally, a lack of robust recycling impacts on wealth creation, lost opportunity for resource recovery, and environmental and sustainable development. Moreover, for East African Countries to fully exploit the potential of recycling in their urban planning, a mindset shift is required to transform their policies and regulatory framework in waste management, to focus on the circular economy, promoting collaboration and innovation in every sector.

Conflict of interest

There is no conflict of interest.

Author details

Ogutu Florence* and Kathambi Bessy*
Department of Earth and Climate Sciences, University of Nairobi, Nairobi, Kenya

*Address all correspondence to: florence.akinyi@gmail.com; k22bessy@gmail.com

IntechOpen

© 2025 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. 

References

- [1] Kaza S, Yao LC, Bhada-Tata P, Van Woerden F. What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. Urban Development, World Bank; 2018. Available from: <http://hdl.handle.net/10986/30317>. License: CC BY 3.0 IGO
- [2] Godfrey L, Tawfic Ahmed M, Giday Gebremedhin K, Katima HYJ, Oelofse S, Osibanjo O, et al. Solid waste management in Africa: Governance failure or development opportunity? In: Edomah N, editor. Regional Development in Africa. London, UK: IntechOpen; 2020. Available from: <https://www.intechopen.com/books/regional-development-in-africa/solid-waste-management-in-africa-governance-failure-or-development-opportunity>
- [3] Gilbert N, Ziqiang Y, Hongzhi M. Current situation of solid waste management in east African countries and the proposal for sustainable management. African Journal of Environmental Science and Technology. 2021;**15**(1):1-15
- [4] Ogutu FA, Kimata DM, Kweyu RM. Partnerships for sustainable cities as options for improving solid waste management in Nairobi city. Waste Management and Research. 2021;**39**(1):25-31
- [5] UNEP, ISWA. Global Waste Management Outlook 2024 - Beyond an Age of Waste: Turning Rubbish into a Resource. Nairobi, Kenya: UNEP/ISWA; 2024. Available from: <https://wedocs.unep.org/20.500.11822/44939>
- [6] Ogutu FA. Assessment of the Effectiveness of the Policy Framework in Solid Waste Management in Nairobi City County. Nairobi: University of Nairobi; 2019
- [7] UNEP. African Waste Management Outlook. Nairobi, Kenya: UNEP; 2018. Available from: <https://wedocs.unep.org/handle/20.500.11822/25514>
- [8] Mecheo NO, Kathambi B, Moronge J. Governance gaps in economic valuation of solid wastes for environmental sustainability in Kisii town. GEP. 2025;**13**(04):310-326
- [9] Akinyi Ogutu F, Kathambi B. Recycling gap, Africa's perspective for sustainable waste management. In: Saleh MH, Hassan IA, editors. Recycling Strategy and Challenges Associated with Waste Management Towards Sustaining the World. London, UK: IntechOpen; 2023. Available from: <https://www.intechopen.com/chapters/84955>
- [10] NEMA. Environmental Best Practices In Waste Management. Nairobi: NEMA; 2024. Available from: <chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://ad.nema.go.ke/wp-content/uploads/2024/10/Environmental-Best-Practices-in-Waste-Management.pdf>
- [11] Kabera T, Wilson DC, Nishimwe H. Benchmarking performance of solid waste management and recycling systems in East Africa: Comparing Kigali Rwanda with other major cities. Waste Management and Research. 2019;**37**(1_suppl):58-72
- [12] Republic of Rwanda. Rwanda, State of the Environment and Outlook Report. Rwanda: Republic of Rwanda; 2017. Available from: <chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.rema.gov.rw/fileadmin/templates/>

Documents/rema_doc/SoE/Rwanda%20SOER%202017%20SPM.pdf

[13] Kaza S, Bhada-Tata P. Decision Maker's Guides for Solid Waste Management Technologies. Urban Development Series Knowledge Papers. World Bank; 2018. Available from: <http://hdl.handle.net/10986/31694>. License: CC BY 3.0 IGO

[14] AFI. Waste Recycling Opportunities in Africa: Profit with Purpose. Waste Recycling Opportunities in Africa: Profit with Purpose. 2024. Available from: <https://africaforinvestors.com/blogs/waste-recycling-opportunities-in-africa-profit-with-purpose>

[15] Kathambi BE, Ogutu FA. Ecological impacts of improper waste management frameworks on biodiversity conservation in Nairobi County, Kenya. *Journal of Biodiversity and Environmental Sciences*. 2021;19(2):91-101

[16] GoK. Sustainable Waste Management Act. Sect. CAP. 387C, Vol. CXXIV—No. 158 2022. Available from: <https://new.kenyalaw.org/akn/ke/act/2022/31/eng@2022-12-31>

[17] Government of Kenya GOK. Kenya Vision 2030. Nairobi, Kenya: Ministry of Planning and National Development; 2007. Available from: <http://vision2030.go.ke/inc/uploads/2018/05/Vision-2030-Popular-Version.pdf>

[18] NEMA. Waste Management Regulations 2016. Nairobi: NEMA; 2016. Available from: <http://nema.go.ke/images/Docs/Awariness%20Materials/Environmental%20sustainability%20performance%20targets%20and%20reporting%20guidelines%20for%202016-17.pdf>

[19] UNEP. Global Waste Management Outlook Report in Africa. Nairobi: UNEP; 2019

[20] Kenya Association of Manufacturers. SDGs READINESS REPORT. Nairobi, Kenya: Kenya Association of Manufacturers; 2020. Available from: www.kam.co.ke

[21] Ecobana Limited. 2020. Available from: <https://www.ecobana.co.ke>

[22] JICA. The Study of Solid Waste Management in Nairobi City. Nairobi: JICA; 2014. Available from: <http://www.nairobi-swm-project.or.ke>

[23] European Biogas Association (EBA). 2025. Available from: <https://www.europeanbiogas.eu>

[24] WRI. How a Partnership in Kenya Recycled 100,000 Kilograms of Fashion Waste. Nairobi: World Resource Institute; 2021. Available from: <https://www.wri.org/insights/closing-loop-textile-waste-recycling-kenya>

[25] Ajira T. Annual Impact Report 2024. Tanzania: Taka ni Ajira; 2024. Available from: <http://takaniajira.org/wp-content/uploads/2019/05/Annual-Impact-Report-2024.pdf>

[26] World Bank. International Solid Waste Association (ISWA). World Bank/ISWA: Waste Management; 2019

[27] RPRA. Annual Report 2023. Canada: Resource Productivity and Recovery Authority; 2023. Available from: chrome-extension://efaidnbmnnnibpajpcpgclefindmkaj/https://rprra.ca/wp-content/uploads/Final-English-2023-RPRA-Annual-Report_Jan-2025.pdf

[28] Kumar C, Bailey-Morley A, Kargbo E, Sanyang L. Waste Management in Africa: A Review of Cities' Experiences. ODI Working Paper. London: ODI; 2022. Available from: www.odi.org/en/publications/

waste-management-in-africa-a-review-of-cities-experiences

[29] Kiggundu AT. Assessing solid waste Management in Kampala City, Uganda: A case study of Nakawa urban division. CUS. 2024;**12**(03):419-439

[30] Aryampa S, Maheshwari B, Sabiiti E, Bateganya NL, Bukenya B. Status of waste Management in the East African Cities: Understanding the drivers of waste generation, collection and disposal and their impacts on Kampala City's sustainability. Sustainability. 2019;**11**(19):5523

[31] Zero Waste Amazing Projects Foundation. Issues and Challenges around Waste Management and Recycling in Kampala. Uganda: Zero Waste Amazing Projects Foundation; 2024. Available from: <https://zwapfoundation4.wordpress.com/2024/09/05/issues-and-challenges-around-waste-management-and-recycling-in-kampala/>

[32] Edodi S. Managing the environment: Issues and priority actions for sustainable waste management in Uganda. African Geographical Review. 2023;**42**(3):342-356

[33] Geme T, Nijman E, Ntawuhiganayo EB, Negesa D. Stakeholder knowledge and perceptions of the circular economy in Ugandan cities. Frontiers in Sustainability. 2023;**4**:1117814

[34] Komakech AJ, Banadda NE, Kinobe JR, Kasisira L, Sundberg C, Gebresenbet G, et al. Characterization of municipal waste in Kampala, Uganda. Journal of the Air and Waste Management Association. 2014;**64**(3):340-348

[35] Castellani P, Ferronato N, Barbieri J, Menya E, Carnevale Miino M, Torretta V. Solid waste management in Ugandan

developing cities: Material flow analysis and sustainable practices for reducing the global warming potential. Waste Management and Research. 2024;**43**(7):1099-1111. DOI: 10.1177/0734242X241291940

[36] Republic of Uganda. National Strategy for Management of Plastic Pollution (2023-2028). Uganda: NEMA; 2023. Available from: https://www.nema.go.ug/new_site/wp-content/uploads/2024/05/Plastic_circularity-Report-2023-1.pdf

[37] Richmond A, Myers I, Namuli H. Urban informality and vulnerability: A case study in Kampala, Uganda. Urban Science. 2018;**2**(1):22

[38] Palfreman J. Waste Management and Recycling in Dar es Salaam. Tanzania; 2014. Available from: <http://rgdoi.net/10.13140/2.1.3196.4482>

[39] Kombe GG, Shemsanga C. Sustainability and economic potential of solid waste generated in Tanzania's largest university campus. Environmental Quality Management. 2024;**33**(4):365-378

[40] Kihila JM, Wernsted K, Kaseva M. Waste segregation and potential for recycling - A case study in Dar es Salaam City, Tanzania. Sustainable Environment. 2021;**7**(1):1935532

[41] Charles G. Sustainability of social enterprises involved in waste collection and recycling activities: Lessons from Tanzania. Journal of Social Entrepreneurship. 2021;**12**(2):219-237

[42] Ngowi NJ, Ngalawa AA. Recycling for deforestation reduction in Tanzania: Why are households not using waste charcoal? Asian Journal of Advanced Research and Reports. 2023;**7**(1):1-8.

Available from: <https://smujo.id/ajf/article/view/11706>

Evidence from small-scale firms in Tanzania. JPDS. 2025;18(1):151-161

[43] Senzige JP. The potential for solid waste recycling in urban area of Tanzania: The case of Dar Es Salaam. IJEPP. 2014;2(5):147

[50] Onesmo C, Mabhuye EB, Ndaki PM. A synergy between sustainable solid waste management and the circular economy in Tanzania cities: A case of scrap metal trade in Arusha City. Urban Forum. 2024;35(1):47-64

[44] Nyampundu K, Mwegoha WJS, Millanzi WC. Sustainable solid waste management measures in Tanzania: An exploratory descriptive case study among vendors at Majengo market in Dodoma City. BMC Public Health. 2020;20(1):1075

[51] Atin B, Siddharth GS. An Assessment of the Solid Waste-Management Ecosystem. New Delhi: Centre for Science and Environment; 2021. Available from: <https://www.cseindia.org/content/downloadreports/10947>

[45] Ali AI, Okafor CJ, Hassan JK, Abdulla SA, Khamis MM, Said OM, et al. Understanding segregation and recycling practices of tin cans and plastic bottles in the household, municipality, and agency in Zanzibar. International Journal of Tropical Disease and Health. 2021;42(8):44-55. DOI: 10.9734/ijtdh/2021/v42i830477

[52] Nipe fagio. Zero Waste Model Dar-es Salaam Case Study. Tanzania: Nipe Fagio; 2024. Available from: <https://nipefagio.co.tz/>

[46] UN-Habitat. A Better Quality of Life for all in Anurbanizing World- Tanzania Country Brief. Tanzania: UN-HABITAT; 2023. Available from: https://unhabitat.org/sites/default/files/2023/07/tanzania_country_brief_final_en.pdf

[53] UNEP. Africa Waste Management Outlook. Nairobi: UNEP; 2018. Available from: <https://www.csir.co.za/documents/africa-wmo-report>

[47] Mapunda AS, Kimwaga RJ, Kassuwi SA. Modeling solid waste minimization performance at source in Dar es Salaam City, Tanzania. GEP. 2024;12(09):17-32

[54] GGGI. Accelerating Green Growth: Gratitude, Resilience, Impact and Opportunit-Annual Report. Korea: Global Green Growth Institute; 2022. Available from: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://gggi.org/wp-content/uploads/2023/06/GGGI_AnnualReport2022.pdf

[48] Fanrpan. Policy Brief: Opportunities for Transitioning to Circular Food Systems In Tanzania. South Africa: FANRPAN; 2025. Available from: <https://www.esrf.or.tz/wp-content/uploads/2025/01/POLICY-BRIEF-Opportunities-for-Transitioning-to-Circular-Food-Systems-in-Tanzania-v4-28012025-2.pdf>

[55] Global Methane Initiative. Global Methane Emissions and Mitigation Opportunities. USA: Global Methane Initiative; 2024. Available from: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.globalmethane.org/documents/analysis_fs_en.pdf

[49] Nyaulingo S. Role of education in shaping recycling investment decisions:

[56] E4Impact. Waste Management and Recycling: Africa Is Changing. Nairobi, Kenya: E4Impact Foundation; 2025. Available from: <https://e4impact.org/>

recycling-and-enterprise-e4impact-
entrepreneurs-changing-africa/

[57] Ellen M. Circular Economy In
Africa: Examples and Opportunities
Public Policy Public Policy. Nairobi:
Ellen Macarthur Foundation; 2025.
Available from: chrome-extension://
efaidnbmnnnibpcjpcglclefindmkaj/ht
tps://content.ellenmacarthurfoundation.
org/m/700a2e091283a13b/original/
Circular-economy-in-Africa-Public-
policy.pdf

*Edited by Amjad Almusaed, Asaad Almssad,
Ibrahim Yitmen and Jonn Are Myhren*

Smart Cities – Designing the Future of Urban Living presents a scholarly synthesis of modern smart urbanism, promoting a coherent, standards-compliant lexicon for digital public infrastructure, AI governance, and human-centered design. The volume connects theory and practice by turning normative frameworks such as equity, resilience, sustainability, and democratic legitimacy into practical advice on interoperability, outcome-based metrics, algorithmic transparency, rights-preserving security, energy systems transition, and circular economy practices. Readers will find helpful tools, such as governance patterns and procurement agreements, indicators and assessment rubrics, and finance concepts that turn pilots into long-lasting public value. Some of its unique strengths are its ability to compare different urban settings, its focus on multi-level governance and institutional capacity, and its insistence that technological “smartness” be shown through measurable improvements in well-being, environmental performance, and public trust. Written for city leaders and planners, engineers and educators, researchers and policy professionals, the book shows how to turn ideas into actions that can be held accountable. It connects data architectures to service quality, participatory co-production to legitimacy, and open standards to learning and scalability. This book provides readers with a solid foundation for planning the future of city living through a short, authoritative, methodologically sound, policy-relevant, and implementation-ready roadmap.

*Usha Iyer-Raniga,
Sustainable Development Series Editor*

Published in London, UK

© 2025 IntechOpen
© Andre2013 / iStock

IntechOpen

ISSN 2753-6580

