

Article

Digital Revolution: Emerging Technologies for Enhancing Citizen Engagement in Urban and Environmental Management

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Abstract: Citizen participation is key in urban planning, but traditional methods are often limited in terms of accessibility and inclusion. This study investigates how the use of emerging technologies such as Virtual and Augmented Reality (VR/AR), Digital Twin (DT), Building Information Modelling (BIM), Artificial Intelligence (AI), and Geographic Information Systems (GIS) can enhance citizen participation in urban planning. Through the review and analysis of existing literature, combined with the study of cases from cities in Eurasia and North America on the implementation of these technologies in urban and environmental planning, the results indicate that the use of multi-reality technologies facilitates immersive visualization of urban projects, allowing citizens to better understand the implications of proposed changes. Furthermore, the integration of real-time monitoring, such as forest and climate surveillance, improves environmental control. Technologies like AI and GIS also enable greater precision and empowerment in participatory decision-making. Nevertheless, the emergence of these technologies presents a challenge that must be addressed, as it is essential to establish a regulatory framework to ensure their responsible use. In conclusion, these platforms not only increase participation and co-creation but also enable more efficient, sustainable, and inclusive urban planning. Greater adoption of these technologies is suggested to optimize the urban decision-making process.

Keywords: co-creation; co-design; crowdsourcing; emergent technologies; smart cities; citizen action; landscape governance; digital transition; sustainable development; digital challenges



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1. Introduction

Planetary urbanization has led to an unprecedented transformation of the global environment, creating complex networks of social, economic, and ecological interaction. Urban areas represent not only the epicenter of human activity but also a significant source of negative environmental impacts facing our planet [1–3]. This urban expansion is manifested in the extension of the anthroposphere—the space inhabited, modified, and exploited by humans—which increases pressures on natural resources, biodiversity and ecological systems globally [4]. In response to these challenges, multiple governance frameworks have been formulated that advocate for more sustainable and inclusive urban planning, recognizing citizen participation as a key pillar to ensuring that urban decisions reflect the needs of all stakeholders [5,6]. However, traditional models of urban and environmental governance present significant obstacles, especially in terms of citizen participation, which hinders the effective implementation of policies that respond to the needs of communities and the complexities of the environment [7,8].

Among the main obstacles is the fragmentation of planning processes, where decisions are often made in administrative silos without effective coordination between the different areas of urban governance [8,9]. This fragmentation prevents policies from responding comprehensively to the complex and multidimensional needs of cities, resulting in partial

solutions that are often decontextualized from the local environment. In addition, historical resistance to citizen participation, often seen as a challenge to the authority of urban planners, has generated a top-down approach to decision-making, leaving out the voices of affected communities [9,10].

Another major obstacle is citizens' lack of access to relevant technical information, which limits their ability to understand the impact of urban decisions on their environments [11]. This information barrier perpetuates a disconnect between planners and citizens, resulting in policies that often do not reflect the true needs of the population. In addition, the lack of transparency in planning processes and the perceived exclusion of citizens have eroded trust in urban institutions, increasing distrust and reducing collaboration among stakeholders [12,13].

This exclusion of citizens in urban planning and environmental management processes generates a disconnect between the decisions of authorities and local realities, which can result in deficient policies that do not respond to critical urban development issues. This is particularly relevant in the context of the Sustainable Development Goals (SDGs), where the targets for sustainable cities and communities (SDG 11) and for strengthening inclusive and transparent institutions (SDG 16) rely heavily on active collaboration between citizens and authorities [14,15]. Therefore, achieving these goals demands innovative approaches that facilitate greater inclusiveness and co-creation in urban and environmental management [16].

These barriers to citizen participation underline the need for innovative approaches and emerging technologies that facilitate a more inclusive and collaborative model of urban and environmental planning. Research indicates that emerging technologies can offer powerful tools to transform the urban planning landscape. Technologies such as Virtual Reality (VR), Building Information Modeling (BIM), Geographic Information Systems (GIS), and Digital Twins (DTs) not only facilitate more inclusive access and visualization of complex data but also enable detailed simulations that citizens can understand and interact with [13–15,17,18]. These tools not only increase transparency by making information accessible in real-time but also enable active and collaborative citizen participation, thus overcoming traditional obstacles to urban planning and promoting an inclusive and resilient governance model [13,14].

In this context, in response to these challenges, the central research question of this study arises: How can emerging technologies and participatory methodologies transform urban and environmental planning to promote greater citizen inclusion and collaboration? To address this question, this study explores how integrating emerging technologies—including VR, BIM, Artificial Intelligence (AI), GIS, and DTs—alongside participatory methodologies like crowdsourcing and community monitoring can make urban and environmental planning more inclusive and transparent. By fostering active citizen participation, these tools help align urban outcomes with community needs, enhancing both inclusion and collaboration.

This study is justified by the urgency of adopting urban and environmental planning approaches that respond to the demands of sustainability and resilience in the context of increasing urbanization. By examining how the combination of advanced digital technologies and participatory methods can positively impact decision-making, this work contributes to a deeper understanding of mechanisms that can strengthen urban and environmental governance. Furthermore, it responds to the research priorities on sustainability and governance set out in international frameworks such as the SDGs by providing a detailed analysis of technological tools that can empower citizens as key actors in the management and preservation of their environments. Ultimately, this study provides an innovative perspective on public policy co-creation, addressing contemporary challenges in urban and environmental management and suggesting governance models that strengthen the link between citizens and planners.

2. Contextualizing the Digital Revolution in Citizen Participation

The digital revolution has transformed social, economic, and political dynamics, marking a paradigm shift in the management of cities and the way citizens engage in decision-making processes [19,20]. From the initial advances in computing in the 1940s to the massification of the internet in the 1990s and the expansion of mobile devices, the evolution of digital technologies has been key to redefining citizen participation [21]. This technological framework has facilitated instant communication and unprecedented access to information, empowering citizens to take a more active role in shaping their environment [22,23].

The smart city concept has gained prominence since the late 1990s and early 2000s, in a context characterized by increasing urbanization and the need to efficiently manage urban resources. Initially, smart cities were conceived as environments that integrated information and communication technologies to improve the quality of life and optimize the use of resources. However, their evolution has broadened this vision to include not only technological infrastructure but also a focus on social inclusion and environmental sustainability [24–26].

Smart cities are now defined as urban ecosystems that integrate emerging technologies to promote citizen participation, transparency, and sustainability. The incorporation of concepts such as the Internet of Things (IoT), AI, and GIS emphasizes that technology transcends its function as a mere tool, acting as an enabler of a holistic approach to urban governance [27–29]. These cities implement interconnected devices that provide customizable services, thereby improving the urban experience for residents through the use of technologies such as traffic management systems, building automation, and smart meters [30].

In this context, digital technologies are fundamental for empowering citizens in decision-making. Fuchs [31] highlights that these technologies comprise a variety of tools and platforms that facilitate the creation, sharing and management of information, thus promoting active participation. The digital revolution is also blurring the boundaries between the local and the global, allowing local initiatives and technological developments to have a wider impact. The role of these cities as centers of technological development is crucial, as their innovations are not only adopted locally but also serve as models for other cities around the world [32]. These emerging platforms foster collaboration between citizens, governments, businesses and non-governmental organizations, making it easier to solve common problems more efficiently [26,33].

At the same time, advanced technologies such as AI and DTs empower these smart urban ecosystems. AI, defined as the simulation of human intelligence processes by computational systems, facilitates the analysis of large volumes of data, contributing to more informed decisions in real-time in areas such as traffic management, public safety, and urban planning [34]. The interplay of AI with technologies such as digital twins, which are virtual representations of physical objects or systems, makes it possible to simulate urban scenarios and optimize resource management, contributing to a more sustainable and resilient environment [32,35–40]. GIS are also tools that enable the capture, storage, analysis, and management of data related to positions on the earth's surface, facilitating the assessment of land use and other critical factors that affect urban life [17,41–44].

VR and Augmented Reality (AR) technologies have transformed the interaction of citizens with their urban environment, enabling immersive visualization of development proposals and enhancing dialogue in planning processes [45–47]. VR offers fully immersive experiences in computer-generated environments, while AR superimposes digital information in the real world, enhancing dialogue in planning processes [48]. This type of interaction not only involves citizens in decision-making but also fosters a sense of ownership and shared responsibility in building their cities.

BIM is another relevant concept that refers to the generation and management of digital representations of the physical and functional characteristics of a place. This methodology

enables more effective collaboration between architects, engineers and builders, facilitating the planning, design and management of construction projects [49–53].

Citizen participation has been transformed by the rise of digital technologies, which offer new platforms for dialogue and collaboration [54,55]. This concept implies that citizens are actively involved in making decisions that affect their environment. The digital revolution has enabled more people to access information and participate in consultation, design, and policy-making processes [56,57]. However, it is essential to consider that digitalization also presents challenges, such as the digital divide that can exclude certain groups of society, limiting their ability to participate effectively [31].

Crowdsourcing initiatives represent an innovative way of mobilizing collective capacities to solve urban problems by allowing people to contribute ideas and solutions [58]. This is complemented by co-creation and co-design approaches, which emphasize active collaboration between citizens and authorities in the development of urban projects. These practices promote inclusiveness and ensure that interventions reflect the needs and desires of the community [58–60].

Landscape governance becomes a critical aspect of the development of smart cities, where the management of public and natural spaces is done in a participatory manner, ensuring that urban interventions respond to citizens' expectations [61]. In this context, multi-scalar projects are fundamental, as they address urban problems from multiple levels of intervention. These projects, which involve diverse actors—local governments, non-governmental organizations, and the community—allow for a more coordinated approach to address challenges such as environmental sustainability and urban resilience [62,63].

The digital transition involves a continuous process of transformation of social, economic, and political systems through digitization. While this revolution offers significant opportunities, it also poses challenges such as privacy, data security, and equity of access to technology. Addressing these concerns is crucial to ensure that the digital revolution benefits all citizens. The interrelationship of these concepts in the context of the 'Digital Revolution' is essential to understanding how emerging technologies can enrich citizen engagement in urban and environmental management. As technologies continue to evolve, it is imperative to develop strategies that ensure all citizens have a voice and agency in shaping their environments, promoting a more resilient and collaborative future.

3. Materials and Methods

This study adopts a qualitative and comparative methodology to investigate the impact of emerging technologies on citizen participation in urban planning and management. It uses a qualitative approach that combines a comprehensive literature review with a comparative analysis of various case studies, which strengthens the validity of the qualitative analyses. Information was obtained from a variety of online sources, both from official sites (governmental institutions, cities, projects, etc.) and reliable third parties (specialized sites, academic journals, national and international entities, stakeholder organizations, and companies, among others), with a view to providing a comprehensive and reliable perspective.

Figure 1 illustrates the methodological approach adopted to analyze the impact of emerging platforms on citizen participation and urban and environmental management. This methodological process starts with a review of three fundamental concepts: digital technologies, citizen participation, and multi-scale projects, which serve as a theoretical framework for this study. From this context, a research focus is established on the intersection between technological platforms, citizen engagement and urban management, which guides the comparative analysis and cross-checking of data, looking for significant relationships between the selected variables.

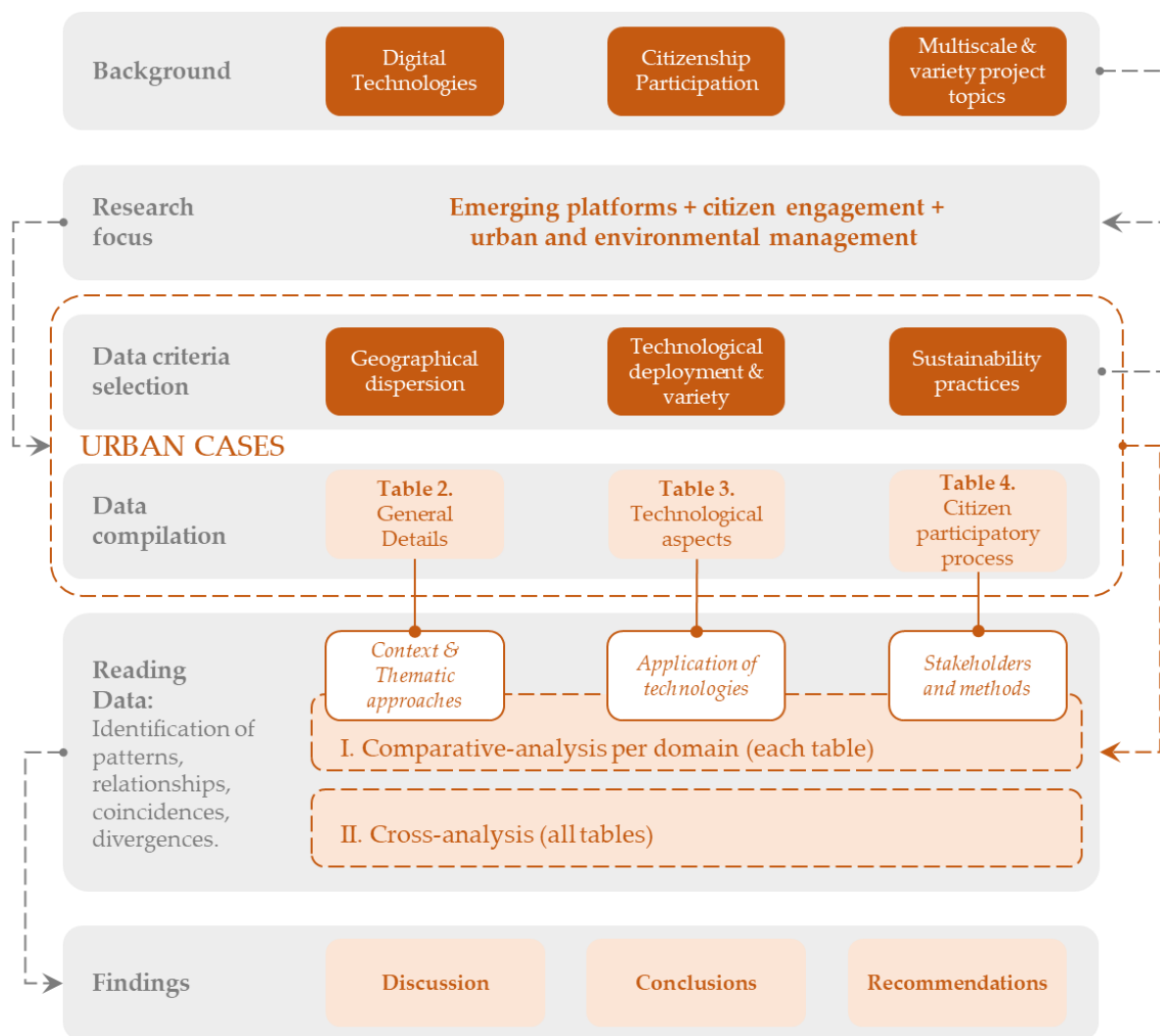


Figure 1. Methodological approach to analysis.

3.1. Phases of the Research

The methodology was structured in three main phases: the theoretical review of key concepts, the selection and organization of the case studies, and a two-level data analysis. These phases are:

- **Background:** The study is grounded in the intersection of digital technologies, citizen participation, and a variety of multi-scale project topics across cities. The rapid growth of digital platforms enables more inclusive governance, fostering collaboration between citizens, government agencies, and private sectors in managing cities and addressing environmental challenges. By examining how these tools support sustainable urban management, the study offers key insights for creating resilient, adaptable cities responsive to today's social and environmental demands. This issue is well addressed in the first and second sections of this document.
- **Research focus:** A comprehensive review of key concepts was conducted in three main areas: digital technologies applied to urban planning, models of citizen participation, and multi-scale projects in urban environments. This review establishes the conceptual basis for analyzing the intersection between technology, citizen participation, and sustainability.
- **Data criteria selection:** A diverse group of six cities was selected according to criteria of geographical dispersion, technological deployment and variety, and sustainability practices. This selection enables a comparative analysis of different technological

approaches and citizen participation models, providing a representative sample of innovative urban projects.

- **Data compilation:** Data were gathered from various sources, including official city reports, technological implementation records, and documentation of participatory initiatives. This data collection process ensured a robust and relevant foundation for each city, covering key aspects such as urban technological deployment, methods of citizen engagement, and sustainability practices. The organization and systematization of information for each city were structured into three tables to facilitate analysis (Figure 1). The first table provides the general context of each case, the second focuses on specific technological aspects, and the third details the methods of citizen participation used.
- **Reading data:** The structured approach—*data compilation into tables*—enabled a detailed comparative analysis within each area, allowing for the identification of patterns, relationships, and divergences in the interaction between technology and citizen participation. The analysis was conducted in two stages: first, a comparative analysis within each table, and second, a cross-analysis across all tables. This dual approach provided a comprehensive understanding of the dynamics in each area.
- **Findings:** A reflective reading of the data was conducted, involving detection, interpretation, and integration of key information to identify relevant findings. This process allowed for an in-depth discussion and debate on the impact of emerging technologies on urban sustainability and citizen participation, serving as a foundation for the study's conclusions.

3.2. Scope of the Research

For the development of the research, a multiple scope was defined that encompasses four dimensions: conceptual, material, temporal, and spatial.

- **Conceptual scope:** The research explores “digital participation” as a model of citizen involvement in urban planning promoted using emerging technologies. This model emphasizes the role of digital platforms such as the DT, VR, AI, and BIM in promoting inclusive and collaborative participation in the management of urban projects and policies.
- **Material scope:** The implementation of emerging technologies in urban projects in six cities with different levels of development and commitment to sustainability is analyzed. This includes the analysis of specific technologies (such as IoT, 5G, and DTs) and their impact on areas such as climate resilience, energy efficiency, and sustainable mobility, with a special focus on citizen inclusion.
- **Time scope:** The research covers the period from 2010 to 2024, allowing for an up-to-date view of the adoption and impact of digital technologies on urban sustainability and citizen participation. This timeframe coincides with two key milestones: Europe’s Digital Agenda, launched in 2010, which boosted the digital economy in Europe and promoted the role of smart cities in the transition to a digital society; and the expansion of BIM, which started to be widely applied in architecture, construction and infrastructure, transforming the design and management of urban spaces. Both milestones represent a paradigm shift: Europe’s Digital Agenda positions cities as drivers of digital innovation, while BIM promotes collaborative and efficient information management, with a significant impact on urban sustainability and resilience.
- **Spatial scope:** The study focuses on urban projects where the implementation of digital technologies plays an essential role in six cities in the northern hemisphere. This region is a hub of technological innovation and urban development, driven by collaboration between universities, businesses, government agencies and other stakeholders.

3.3. Selection of Cities

For this study, a city selection process was established based on objective criteria, avoiding any bias towards specific cases and ensuring a balanced representation of different

urban contexts. First, a preliminary list of some 43 cities was generated, corresponding to the cities with the greatest progress in the implementation of smart city technologies, using five recognized international indices that measure key factors such as technological innovation, sustainability, quality of life, digital infrastructure, and citizen participation.

The selected indices include the *Cities in Motion Index* (CIMI) [64,65], which assesses sustainable urban development and quality of life; the *Smart City Index* (SCI) [66,67], which ranks cities based on their adoption of smart technologies; the *Global Power City Index* (GPCI) [68,69], measuring cities' attractiveness; the *Global Cities Index* (GCI) [70,71], which evaluates economic growth potential; and the *Innovation CitiesTM Index* (ICI) [72], focused on innovation and talent.

Only cities that ranked in the top 25% in at least three of the five selected indices were included in the list. This was determined by dividing the total number of cities analyzed in each index by four to establish a ranking threshold. Cities that appeared in the top positions below this threshold were considered to be in the top 25% (Table 1). This list of 100 cities was then divided by geographic region—North America, Europe, and Asia—to ensure equal representation. From this ranking, two cities were randomly selected from each region, forming a representative sample of six cases: Helsinki, Copenhagen, Tokyo, Dubai, New York, and Toronto (marked in light-gray in Table 1). This method eliminates possible influences of special interests in the selection, allowing the analysis to focus exclusively on how emerging technologies impact citizen participation processes in diverse urban contexts.

Table 1. Ranking of the 43 cities with a high level of technological performance.

	CIMI	SCI	GPCI	GCI	ICI
	(Year 2024)	(Year 2024)	(Year 2023)	(Year 2024)	(Year 2023)
Amsterdam	8	18	6	28	20
Barcelona	29	81	22	73	26
Basel	24	N/A	N/A	37	65
Berlin	5	37	10	43	11
Copenhagen	11	6	11	15	30
Dublin	34	69	28	12	36
Edinburgh	32	N/A	N/A	82	103
Geneva	40	4	26	21	98
Hamburg	16	14	N/A	56	41
Helsinki	26	9	31	38	39
London	1	8	1	2	2
Madrid	20	35	14	47	19
Manchester	36	71	N/A	75	86
Munich	14	21	N/A	32	16
Oslo	7	2	N/A	19	34
Paris	3	49	4	5	4
Prague	50	15	N/A	64	59
Reykjavik	23	26	N/A	138	169
Rotterdam	25	41	N/A	63	87
Stockholm	18	11	16	14	13
Tallinn	72	24	N/A	198	102
Vienna	22	23	13	49	17
Zurich	12	1	19	10	54

Table 1. Cont.

	CIMI	SCI	GPCI	GCI	ICI	
	(Year 2024)	(Year 2024)	(Year 2023)	(Year 2024)	(Year 2023)	
<i>Austin</i>	45	N/A	N/A	39	44	
<i>Boston</i>	15	36	29	11	7	
<i>Chicago</i>	10	67	25	29	12	
<i>Los Angeles</i>	39	68	21	7	6	
<i>New York</i>	2	34	2	1	3	
<i>Seattle</i>	31	63	N/A	6	21	
<i>Toronto</i>	33	51	23	17	15	
<i>Abu Dhabi</i>	116	10	N/A	54	75	
<i>Beijing</i>	21	13	17	217	28	
<i>Dubai</i>	81	12	8	92	14	
<i>Hong Kong</i>	37	20	18	76	58	
<i>Seoul</i>	13	17	7	41	8	
<i>Shanghai</i>	44	19	15	278	46	
<i>Singapore</i>	6	5	5	42	5	
<i>Taipei</i>	27	16	35	65	52	
<i>Tokyo</i>	4	86	3	4	1	

Note: The top 25% is indicated in green; outside the top 25% in orange; data unavailable is marked in yellow; light-gray indicated the cities selected; blue, orange and gold designate the geographic regions for Europe, North America and Asia, respectively.

These cities, located in the northern hemisphere, are at the epicenter of human activity and technological advancement, driven by industrial and digital development. Toronto, New York, Copenhagen, Helsinki, Dubai, and Tokyo are not only centers of innovation but also examples of how urban environments are becoming key platforms for the digital revolution. Globally, cities act as nodes in a vast network of technological and economic infrastructures, shaping what is known as the Anthroposphere (Figure 2): a term that captures the footprint of human activity on the planet in both infrastructural and networked aspects with global reach. In this sense, the Anthroposphere is not only a map of the human footprint but also a reflection of the potential that cities have to generate a positive impact through technology and the capacity for global influence as a result of the interdependencies created by globalization [3].

This network of cities, where flows of people, assets, information, and energy converge, is evidence of the socio-economic and technological development achieved by contemporary urban civilizations [2]. Each of these metropolises is located at strategic points in this planetary network, with its own specific geographical characteristics and local challenges, but connected to global systems that not only determine its competitiveness but also its capacity to lead sustainable transformations [73].

In the context of the digital revolution, these cities have become critical platforms where emerging technologies converge that are transforming the way citizens engage in urban and environmental management [74,75]. These cities are not simply large urban centers; they are laboratories of digital innovation that have adopted emerging technologies to enhance citizen participation in the management of their urban environments and natural resources [40,73]. Digital platforms allow citizens not only to interact with their governments more efficiently but also to contribute directly to decision-making. Through these tools, city dwellers are playing a more active role in environmental management, from planning public spaces to implementing solutions to address climate change and promote sustainability [18].

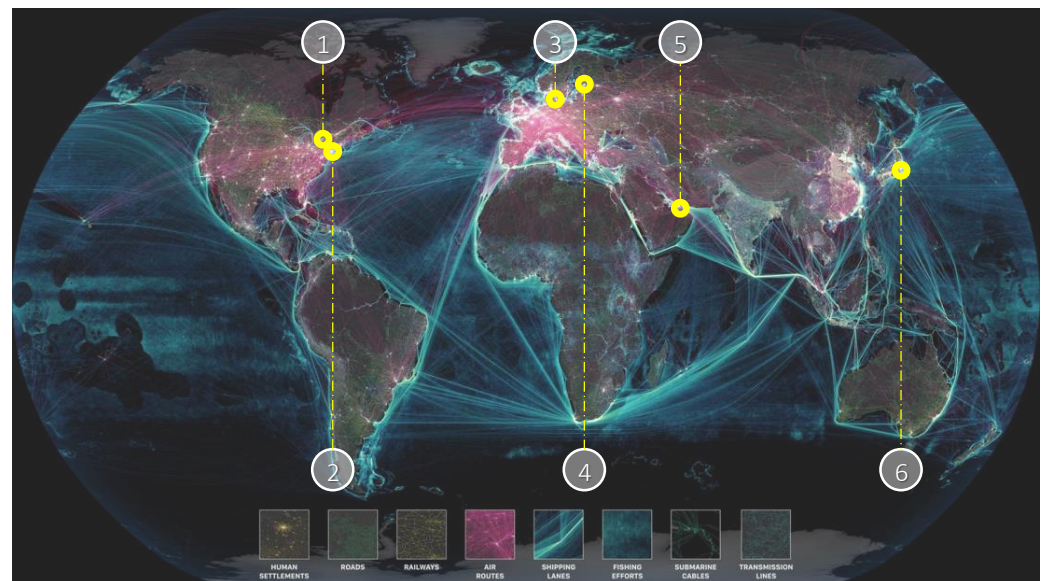


Figure 2. Cases at cities around three continents. Background illustration used The Anthroposphere courtesy of © GLOBAIA. Cities highlighted on the infographics map: 1. Toronto, Canada; 2. City of New York, United States of America; 3. Copenhagen, Denmark; 4. Helsinki, Finland; 5. Dubai, United Arab Emirates; 6. Tokyo, Japan.

3.4. Project Identification

To delve deeper into the implementation of advanced technologies and approaches to citizen engagement, specific projects were selected in each of the cities based on criteria that allow for robust comparative analysis. These projects represent a spectrum of innovations, from DTs to IoT integration and 5G networks, and address methods of engagement ranging from collaborative models to technocratic approaches. This selection seeks to capture contextual variations and differentiated approaches to technology use and participatory management.

The criteria used to select the technologies and participation models in each case study were:

- The integration of advanced technologies in the urban context (e.g., DT, BIM, and AI).
- The diversity of approaches to citizen participation (collaborative or technocratic).
- The commitments made to sustainability goals in the framework of the 2030 Agenda roll-out and the implementation of the SDGs.

This approach also allows for an assessment of how these technologies impact citizen inclusion and participation, thus promoting sustainable practices in city planning and reinforcing the need for innovative solutions to global challenges such as climate change. It represents a significant advance in the development and maturity of citizen science, aligning with the principles of transdisciplinarity, which suggest a proactive and collaborative approach to the inherent complexity of urban issues and conflicts in governance and decision-making. The research thus highlights a shift towards urban management focused on solving specific problems, involving citizens and experts in a dynamic of active collaboration to comprehensively address contemporary urban challenges.

3.5. Organization of Information

For the purpose of structuring and analyzing the data for each project effectively, they were organized into three tables, each with a specific focus that allows for a detailed and comparative analysis of the different aspects of the implemented projects (Figure 2). These tables provide a solid basis for understanding the particularities of each city in terms of context, technology, and citizen participation, facilitating a comprehensive assessment of the impacts and benefits of digital solutions at the urban level:

- **Table 2: General Details.** This table provides a comprehensive overview of each city, including the project context, thematic approaches, and the actors involved. These elements allow for contextualizing the motivations behind each project and understanding how they align with city-specific strategies and objectives. It also provides a comparative view of how different cities address their urban challenges according to their local needs and strategic priorities.
- **Table 3: Technological Aspects.** This table details the specific technologies used in each project, their practical applications and the results achieved. The breakdown includes the type of technology (e.g., DTs, IoT sensors, 5G networks), their implementation in real-world scenarios and how these tools contribute to sustainability objectives. This approach helps to identify patterns of technological innovation, allowing observation of how these technologies are adapted to various contexts and how they support urban transformation in terms of energy efficiency, climate resilience, and carbon reduction.
- **Table 4: Citizen Participatory Process.** This last table describes in detail the citizen participation in the projects, noting the actors involved, the methods used to foster inclusion, and the profile of the participating citizens. This information allows for an analysis of the different models of participation, from collaborative and open approaches to more structured and technocratic ones. The table also provides a comparative analysis of how cities integrate their citizens in the decision-making process and the impact of this participation on the success and acceptance of projects.

This organization in tables allows for a clear and structured assessment of each city and its projects, highlighting similarities and differences in implementation strategies and their outcomes in the context of urban sustainability. Using these three approaches—general context, technology, and participation—provides a multifaceted perspective that helps to visualize the transformative role of technology in cities, both in terms of infrastructure and citizen inclusion.

3.6. Data Analysis

The data analysis is carried out on two levels and is framed within the SET (socio–eco–technological system) [76], as illustrated in Figure 3. This framework focuses on the interaction between three key domains: social–behavioral, ecological–biophysical, and technological–infrastructural, which are essential for understanding the urban ecosystem as an interconnected and complex system. Each of these domains is addressed in separate tables that are analyzed individually by comparing projects, and then further cross-analysis is carried out to examine how the interactions between them affect levels of citizen participation and urban sustainability outcomes.

The SET approach allows the urban ecosystem to be viewed as an interconnected socio–eco–technological system, where each domain co-produces sustainability and participation outcomes. This framework highlights how the interactions between social, ecological, and technological processes reveal challenges and opportunities for fostering inclusive and sustainable urban planning. Furthermore, the SET framework not only facilitates the understanding of urban complexity but also offers an integrative perspective that emphasizes the importance of citizen science and active participation in the transition towards more sustainable cities.

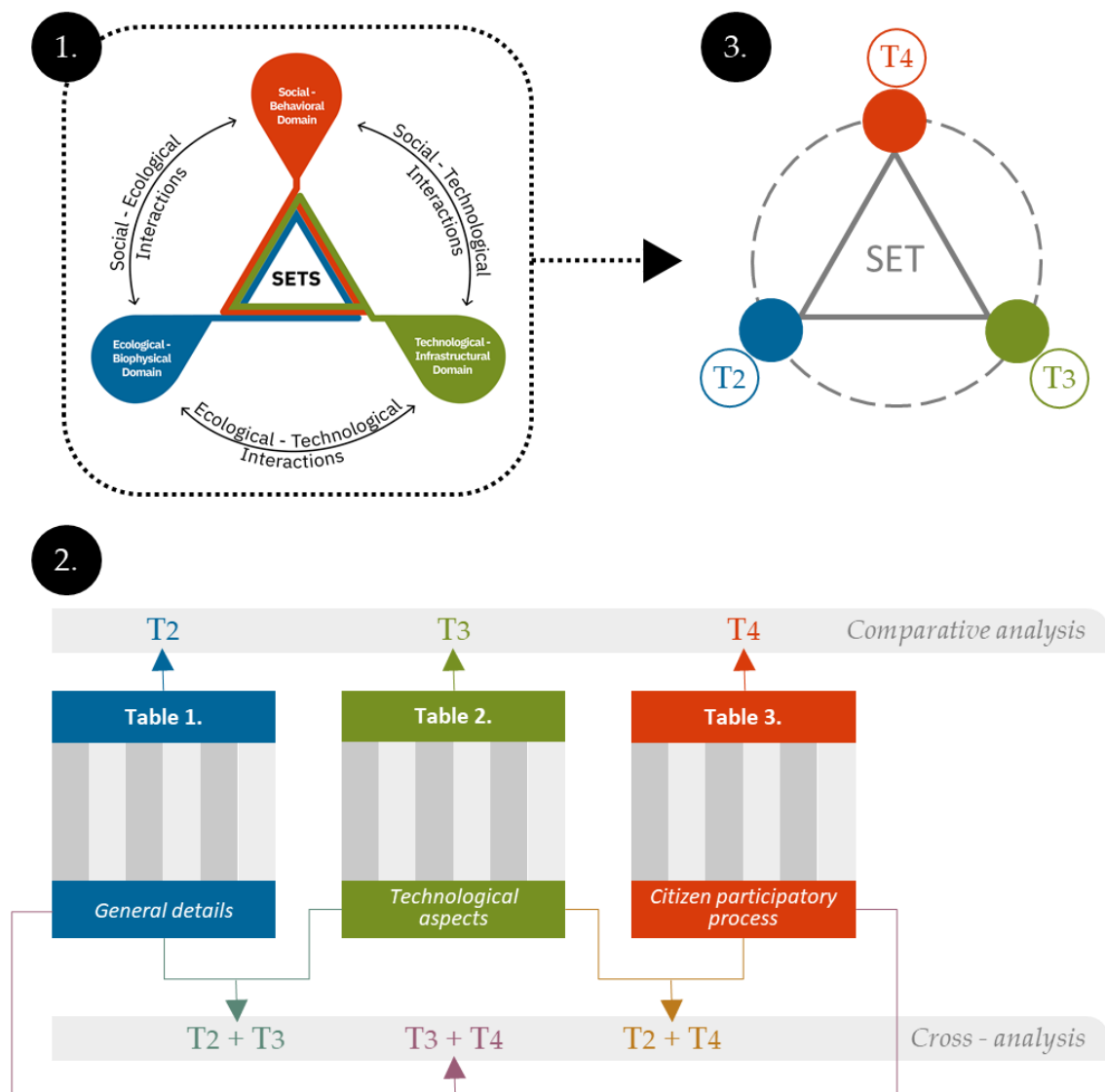


Figure 3. Schematic of the data analysis based on the SET (socio-eco-technological system) framework, illustrating the interaction between the social-behavioral, ecological-biophysical, and technological-infrastructural domains, and their influence on citizen participation and urban sustainability. (1.) SET template [76]: The human ecosystem as socio-eco-technological systems; (2.) Data tables (projects); (3.) Integration data tables with SET template.

3.6.1. Comparative Analysis per Table

Within each table, a comparative analysis is carried out to identify patterns and differences in the approaches of each city.

- **Table 2—General Details (Ecological-biophysical domain):** This table provides general aspects of each project, focusing the analysis on its key ecological and biophysical characteristics that condition urban planning and sustainability. It includes factors such as climate, resilience to natural hazards and other elements that influence the project from an environmental perspective. In the comparative analysis, these ecological aspects are examined in relation to the scope, objectives, and themes of the projects, as well as their impact on urban sustainability.
- **Table 3—Technological Aspects (Technological-infrastructural domain):** This table assesses the technologies implemented in each urban context, such as digital twins, artificial intelligence and other digital infrastructures. This allows exploring how

these technologies can act as disruptors when integrated into the urban environment, contributing to efficiency, sustainability, and resilience. In the comparative analysis, the breadth and depth of the technological infrastructure of each project is contrasted, investigating their potential to model a resilient approach to urban development.

- **Table 4—Citizen Participatory Process (Social-behavioral domain):** This table analyzes the citizen participation strategies adopted in each city, differentiating between collaborative and technocratic approaches. The comparative analysis explores how participatory practices influence urban governance, assessing the impact of digitization and how these methods can vary and adapt to the different socio-cultural contexts of each project.

3.6.2. Cross-Analysis (All Tables)

In addition to the comparative analysis within each table, a cross-domain analysis is carried out to examine the interactions between the domains:

- **Ecological-technological interaction (T2 + T3):** Explores how ecological aspects condition the implementation of technologies and how, in turn, technology can contribute to environmental sustainability, through solutions such as energy efficiency and natural risk management.
- **Social-ecological interaction (T2 + T4):** Analyzes how the biophysical conditions of each city affect citizen participation in environmental issues, and how communities respond to ecological challenges.
- **Social-technological interaction (T3 + T4):** Examines how technological infrastructures influence forms of citizen participation, assessing whether technologies facilitate inclusive and equitable access to urban governance.

4. Case Study Descriptions

In a context of rapid urbanization, several cities have implemented innovative technological projects to address sustainability and resilience challenges, while integrating citizen participation in their processes. The following are general aspects of the case studies that illustrate how each initiative combines technology and community participation to improve urban planning and management.

In Europe, the Helsinki 3D+ project uses a 3D digital model of the city, combined with real-time data, to optimize energy efficiency and urban planning, promoting an open data platform that facilitates the participation of citizens and businesses in urban improvement initiatives (Figure 4). The Cloudburst Initiative in Copenhagen (Figure 5) addresses extreme flooding through green and blue infrastructure, which increases resilience to climate events and allows the community to be involved in the conception and design of these solutions.

In Asia, the Smart Tokyo Initiative (Figure 6) drives the development of advanced digital infrastructure with the aim of improving disaster management and urban quality of life through technological innovation. Similarly, the Smart Dubai Initiative (Figure 7) implements a digital city twin to optimize urban planning and resource management, encouraging citizen participation in one of the fastest growing urban regions.

In North America, Toronto's Quayside Smart Neighbourhood (Figure 8) was conceived as a green and technologically advanced neighborhood, focusing on sustainable urban design and data protection, but was canceled due to privacy concerns. Finally, The BIG U in New York (Figure 9) combines flood protection with the creation of recreational public spaces, using green infrastructure to mitigate the impact of storm surges on the Manhattan waterfront, in an effort that crucially integrates the participation of local communities in the design and decision-making process.

Levels of operation

STRATEGIC GOALS

OPEN DATA

PROCESSES & SERVICES

3D MODELS

DATA

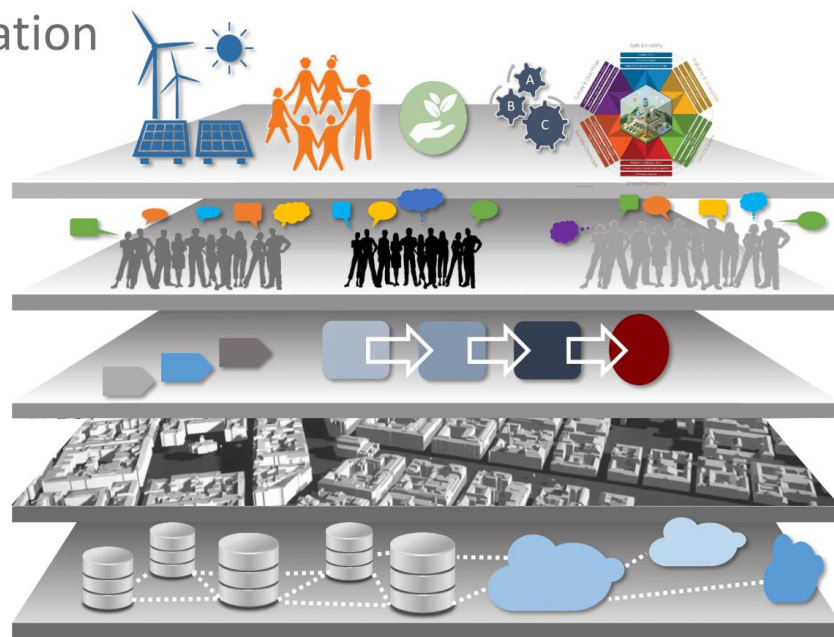


Figure 4. Helsinki 3D+ (Helsinki, Finland). Overview of the AI-assisted Data Highway platform for the integrated management of digital services in mobility, energy, education, and health [77].

Copenhagen Cloudburst Plan

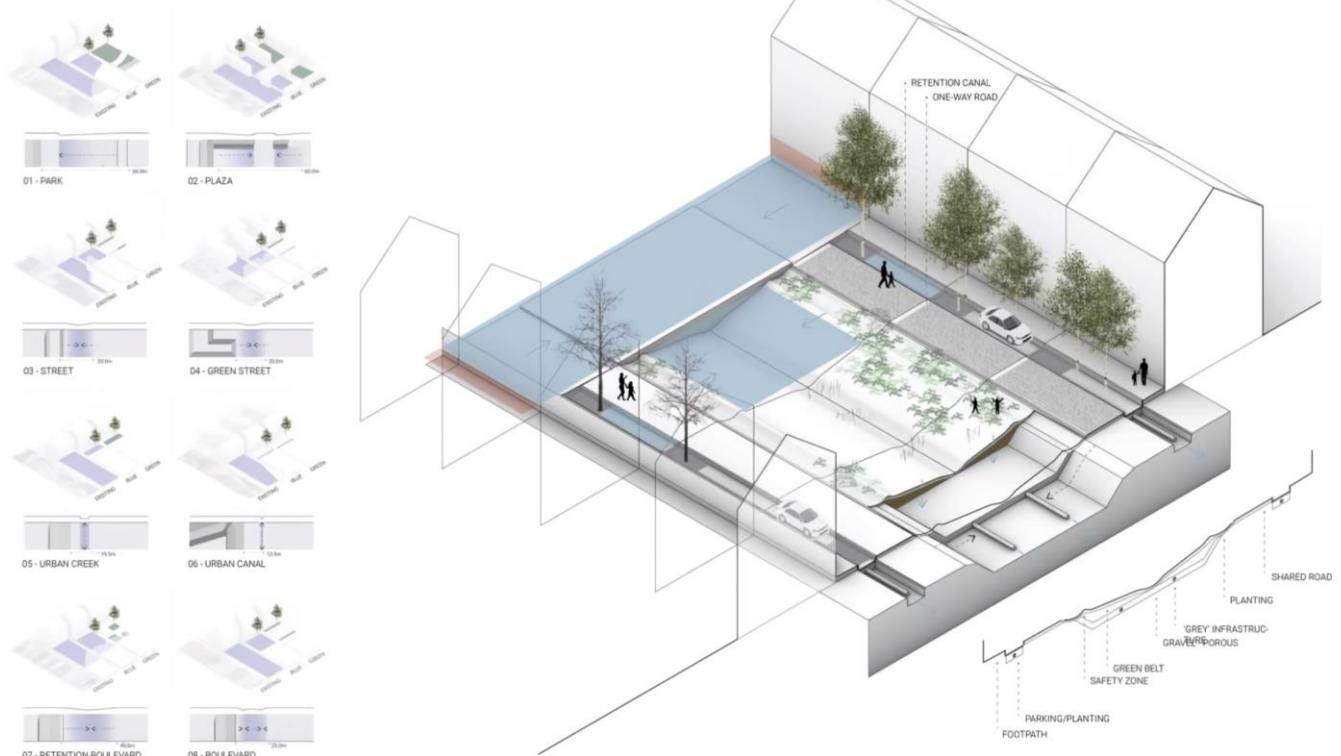


Figure 5. Cloudburst Initiative Copenhagen (Copenhagen, Denmark). An isometric sketch of an urban road section illustrates a drainage system that integrates green and grey infrastructure to manage large volumes of rainwater [78].



Figure 6. Smart Tokyo Initiative (Tokyo, Japan). Overview of the AI-assisted Data Highway platform for integrated management of digital services in mobility, energy, education, and health fields [79].



Figure 7. Smart Dubai Initiative (Dubai, UAE). Visualization of a high-tech project and futuristic architecture reflecting the vision of a smart and advanced city [80].

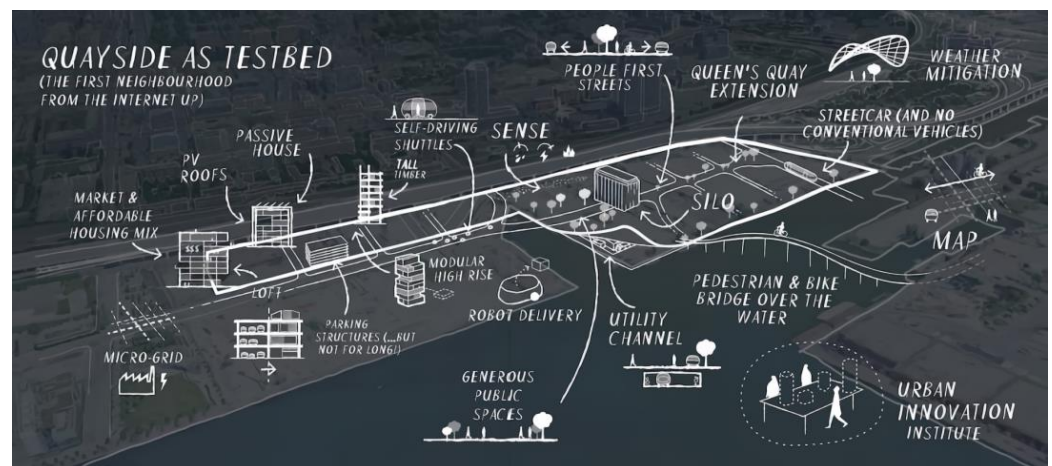


Figure 8. Quayside Smart Neighborhood (Toronto, Canada). A conceptual sketch showing the urban intervention plan concept integrating people-centered urban design with advanced technology [81].

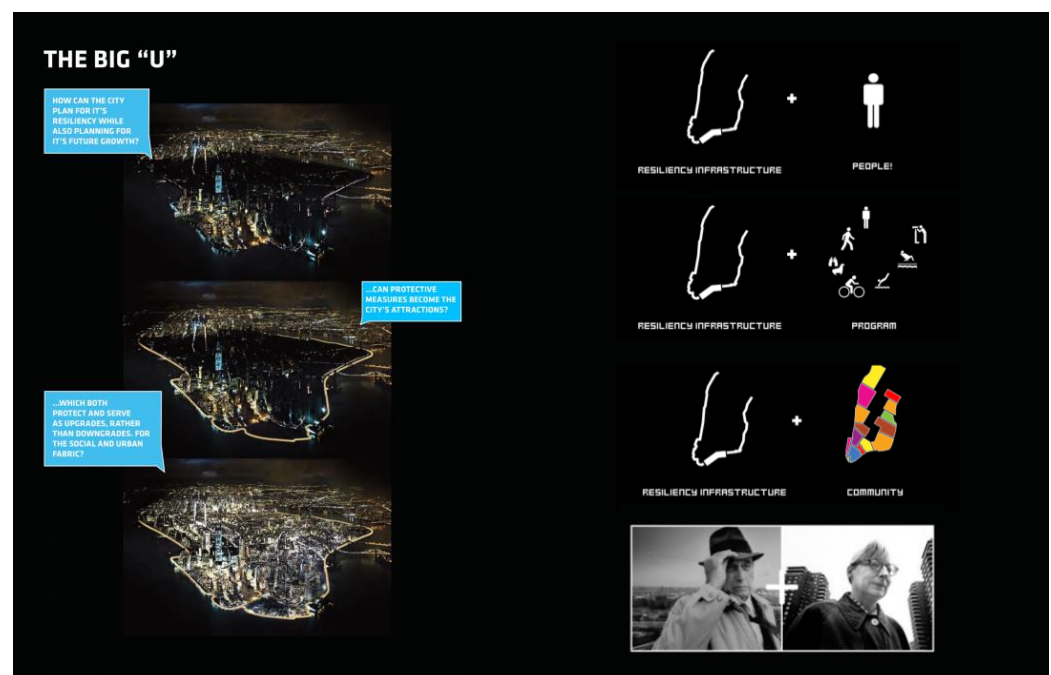


Figure 9. The BIG U: NYC Community Spaces as Barriers for Flooding (New York, USA) Large-scale design approach that integrates a community space program with coastal flood protection measures [82].

Each of these initiatives provides a specific and relevant context for understanding the opportunities and challenges associated with the adoption of emerging technologies and the design of sustainable infrastructure in a global urban context, with particular emphasis on the fundamental role of technology in facilitating participatory decision-making processes. Thus, these projects underline the importance of an inclusive approach to technology implementation, which is critical to successfully address the design and development of projects that respond to the needs of their inhabitants and contribute to collective well-being in urban environments.

5. Results

5.1. Comparative Analysis Within Each Domain per Table

5.1.1. Table 2—Analysis of General Project Data

The analysis of the case studies reveals patterns of overlap, convergence, and divergence in the way various cities address contemporary urban challenges through sustainability and resilience initiatives. The projects, from Helsinki 3D+ to The BIG U in New York, share the goal of promoting sustainability and resilience in the face of issues such as climate change and the growing demand for efficient urban services. While the approach varies, they all integrate sustainability as an essential pillar, applying it through energy efficiency in Helsinki and Tokyo, green infrastructure for flood mitigation in Copenhagen and New York, or the use of digital twin technologies for real-time analysis and planning in Helsinki and Dubai.

A common aspect of several of these projects is the implementation of digital twins and real-time data collection technologies, which enable informed decision-making and contribute to the improvement of citizens' quality of life. Initiatives such as Helsinki 3D+ and Smart Dubai also seek active citizen participation through open data platforms and public visualization services, promoting collaboration between residents and local stakeholders. However, there are significant divergences between the projects.

In terms of scale and geographic focus, initiatives range from local projects, such as the Quayside Smart Neighbourhood in Toronto, to large-scale efforts in denser cities such as Tokyo. This suggests that the resources available and the specific needs of each region have a direct bearing on the structure of projects. The cancellation of Quayside, in part due to data privacy concerns, emphasizes the importance of finding a balance between transparency in data management and citizen inclusion.

Differences in scope, budget, and priorities also reflect variations in local needs. For example, European projects tend to operate with more modest initial budgets, such as Helsinki, with an initial budget of €1 million, compared to the high budgets of projects in Asia and North America, such as €684.61 million in Tokyo or €2.52 billion in New York. Investments in large-scale projects, such as The BIG U and Smart Tokyo, contrast with the resources allocated to smaller-scale initiatives. This indicates that cities with high population density and exposure to climate risks, such as New York, require more substantial investments to develop infrastructure that not only provides protection but also generates social benefits.

In contrast, projects in Asia show a trend toward advanced digitization of urban infrastructure and the development of smart mobility. In Tokyo and Dubai, investment in technology and the digitization of urban infrastructure are driving a transformation towards more connected and efficient cities, while North American projects, such as the canceled Quayside, reflect a concern for data privacy and information control in highly sensorized urban environments.

The patterns of convergence identified in these projects underline a shared approach to urban sustainability and resilience, while the divergences highlight how each city adapts its technological and infrastructural strategies based on its own specific challenges and resources. This analysis highlights the relevance of contextualizing urban initiatives within a framework that considers local needs, citizen expectations and available technological capacities in an integrated manner.

Table 2. General details of the case studies.

General Details							
Year of Start	Project Status	Initial Budget	Spatial & Demographic Scope	Thematic Scope	Short Description	Key Objectives	
Helsinki (Finland)	Helsinki 3D+ [83]						
	2015	Ongoing	€1 million (Initial phase).	Citywide, focusing on approx. 650,000 residents.	- DT, - Energy Efficiency, - Smart City, - Smart building - Urban planning.	The Helsinki DT project combines real-time data with 3D city models to optimize energy management, urban planning, and citizen engagement. The Helsinki 3D+ open data platform now facilitates various initiatives aimed at enhancing sustainability and quality of life through a city-wide DT.	- Create 3D reality models of Helsinki for city visualization and analysis, fostering digital city initiatives. - Implement an open data strategy with residents and businesses to support commercial research and development. - Launch pilot projects showcasing the capabilities of reality modeling technology for practical applications.
Copenhagen (Denmark) [84]	Cloudburst Initiative Copenhagen [85]						
	2011	Ongoing	Above €10 million.	- Whole City & Administrative Region - All city population: 600,000 inhabitants.	- Climate resilience, - Flood Risk Management, - NBS multifunctional support design, - Water management, - Urban & planning design, - Landscaping	A city-wide project focusing on managing extreme rainfall events by developing green and blue infrastructure (e.g., parks, green roofs, canals) to prevent floods.	Enhance urban flood resilience by managing cloudbursts; protect the city’s infrastructure and citizens from climate-related risks.

Table 2. Cont.

General Details							
Year of Start	Project Status	Initial Budget	Spatial & Demographic Scope	Thematic Scope	Short Description	Key Objectives	
Tokyo (Japan)	Smart Tokyo Initiative [86,87]						
	2019	Ongoing until 2040.	€684.61 million (accumulated costs)	Citywide by geographical units.	- Energy efficiency, - Citizenship participation, - Smart City, - Smart building, - Urban planning, - Smart infrastructure, - Smart mobility, - Sustainability	An Initiative aims to transform Tokyo into a more convenient and comfortable city through advanced technologies. By collaborating with startups and creative stakeholders, the project seeks to quickly develop new services that enhance the quality of life (QOL) for residents across various city areas.	- Strengthen the ability to convey - Flood disaster information for management risks. - Enhance the quality of life by leveraging advanced digital infrastructure to improve energy management, mobility, and public services. - Promote efficient urban solutions through technology-driven innovations in collaboration with startups and local stakeholders.
Dubai (United Arab Emirates) [88]	Smart Dubai Initiative [89,90]						
	2016	Ongoing	Digital Strategy 2023–2030, with 82 projects and initiatives at a total investment of €416 million.	Entire city of Dubai (3.3 million residents); aimed at urban planning and smart city development. It covers an area of 2 square kilometers (0.77 sq mi).	- Urban planning, - Sustainability, - Smart infrastructure, - Smart mobility, - Energy, - Smart building, - Smart city - Environment & resilience.	A large-scale digital twin initiative aimed at visualizing future urban developments, enhancing resource management, and optimizing city infrastructure.	- Improve urban planning - Optimize resources through smart monitoring - Foster citizen participation.

Table 2. Cont.

General Details							
	Year of Start	Project Status	Initial Budget	Spatial & Demographic Scope	Thematic Scope	Short Description	Key Objectives
Toronto (Canada)	Quayside Smart Neighborhood [91,92]						
	2017	Cancelled in 2020 after criticism over privacy and data control.	€855 million	4.9 hectares (Lake Ontario shoreline) 12-acre neighborhood; approximately 5000 residents (planned).	- Smart City, - Sustainability, - Urban Development - Data privacy - Smart Mobility - Green Infrastructure.	Quayside aims to integrate cutting-edge technology with sustainable urban design to build an eco-friendly, data-driven neighborhood that improves residents’ lives.	- Foster environmental sustainability - Incorporate green infrastructure and renewable energy sources. - Use real-time data to improve quality of life and urban efficiency. - Create energy-efficient infrastructure - Enhance citizen engagement and quality of life.
New York (United States of America) [93]	The BIG U: NYC Community Spaces as Barriers for Flooding [94]						
	2013 (Initial of plan) 2016 (Started construction).	Ongoing (Phase Implementation).	€2.52 billion total (€1.395 billion initial funding from HUD’s Rebuild by Design initiative).	Lower Manhattan specifically the Financial District (approx. 60,000 residents); Coastal protection for 10-mile stretch & reaches 1,000,000 sq. m. of surface.	- Climate resilience, - Climate change, - Flood protection, - Urban design, - NBS green infrastructure design - Social infrastructure.	A multi-phase project aimed at protecting New York City from coastal flooding through green infrastructure, berms, and recreational areas, designed to absorb storm surges and mitigate flood risks.	To enhance coastal resilience, reduce the risk of future flooding, and provide public spaces that offer both protection and recreational benefits.

Note: Blue, orange and gold designate the geographic regions for Europe, North America and Asia, respectively; light-blue, light-orange and light-gold designates the city scale and additionally in parentheses appears in italic the country.

5.1.2. Table 3—Analysis of Technological Aspects

The transition towards smart cities reflects a growing focus on the use of technology for sustainability, aligned with the SDGs. A pattern of convergence in cities such as Helsinki, Copenhagen, Dubai, and Toronto is the use of advanced technologies, such as IoT, AI, and GIS. These tools enable real-time monitoring and optimize energy, air quality, and traffic management, facilitating accurate responses to urban needs, in line with SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action). Digitization through DTs, 3D models, VR, and AR has increased citizen engagement in cities such as Helsinki and New York. These technologies allow citizens to visualize the impact of urban projects and participate in planning, promoting transparency and social cohesion practices in line with SDG 16 (Peace, Justice and Strong Institutions).

Climate resilience is another converging approach. Cities such as Copenhagen and New York integrate green and blue infrastructure to mitigate floods and extreme weather events, complemented by risk monitoring platforms. This combination strengthens the resilience of urban ecosystems and reduces vulnerability to natural hazards, aligning with SDGs 13 and 15 (Life of Terrestrial Ecosystems).

The commitment to environmental sustainability, a key pillar of the SDGs, is evident in initiatives in cities such as Dubai, Toronto and Helsinki, which integrate renewable energy and simulation technologies to reduce emissions and improve energy efficiency. With concrete results, such as Dubai's 30% increase in energy efficiency and Toronto's 15% reduction in carbon emissions, these projects support SDG 7 (Affordable and Clean Energy) and SDG 13 and show how technology enables measurable progress towards more sustainable urban environments.

However, there are differences in cities' approaches to technology. Cities such as Helsinki and Copenhagen prioritize citizen engagement, while Dubai focuses on operational efficiency through automation and data analytics, reflecting different cultural factors and development goals. Dubai and Tokyo, for example, have embraced emerging technologies such as blockchain and autonomous air transport systems, with the aim of positioning themselves as technology hubs. In contrast, Copenhagen focuses on conventional green infrastructure, tailored to its sustainability and resilience needs, without a predominant focus on disruptive technologies.

There are also differences in implementation timelines. European cities such as Copenhagen develop long-term projects, with infrastructure that aims to mitigate flooding and promote sustainability over a twenty-year horizon. On the other hand, Dubai and Tokyo choose to implement technologies with rapid adoption and immediate results, reflecting a response to demands for short-term economic growth and urban well-being. These variations in timelines and priorities underline diverse approaches to sustainability and smart city development in response to specific socio-economic contexts.

Taken together, these patterns of convergence and divergence in technology adoption reflect that while smart city projects share goals and methods for advancing the SDGs, each city adapts its approaches according to its own priorities and local realities. This diversity allows each city to move towards sustainability and efficiency in its own way, and to become an adaptive model for other regions. As the global urban environment evolves, these differentiated approaches and the strategic adoption of technology position cities as drivers of global sustainability, laying replicable foundations towards a more inclusive, resilient and SDG-aligned urban future.

Table 3. Technological aspects of the case studies.

Technological Aspects										
	Key Technologies		Key Projects		Key Use Cases		Key Outcomes	Key Notes	Impacts	UN SDG's Linked
Helsinki (Finland) [95,96]	Helsinki 3D+									
	GIS, Laser Scanning, Oblique photogrammetry, LIDAR, CAD, DT, 3D City Models, IoT, Smart Energy Systems, AI.	-	Helsinki 3D City Model	-	Simulation of energy-efficient urban planning	-	Improved energy efficiency	The city has also used the 3D models to develop a Minecraft Helsinki, 3D virtual parks, a system for modeling maintenance processes, and better urban analytics including tools for quality indicators for urban space, CO2/GHG/Emission analysis, and solar/wind potential analyses.	In 2020, a study found that public participation in planning initiatives increased by 25%, measured through surveys and engagement metrics [97,98]. This indicates a tangible impact on community involvement in urban planning processes.	SDG 7, SDG 9, SDG 11, SDG 13, SDG 17
		-	Smart Energy Grids	-	Smart traffic and mobility solutions.	-	Enhanced urban planning processes			
		-	IoT Sensors for Urban Monitoring	-	Simulation of urban growth and energy infrastructure,	-	Real-time monitoring and adjustment of city services.			
	-	Real-time monitoring of energy consumption	-	Visualization of carbon emissions in real-time.						
Copenhagen (Denmark) [99,100]	Cloudburst Initiative Copenhagen									
	AI, IoT, GIS, BIM, VR, digital community engagement platform, ground penetrating radar (GPR).	-	Cloudburst Master Plan		Flood risk modeling: AI and GIS predict flood-prone areas; Public engagement platforms allow citizens to view flood risk maps and suggest mitigation strategies.	-	Reduced flood risk: Improved management of urban rainfall events through green and blue infrastructure.	Citizen engagement through participatory platforms. Tokyo will use cutting-edge technology and will implement various accessible and barrier-free initiatives throughout the city.	Copenhagen reported a 40% reduction in flood damage from stormwater management projects, validated through municipal reports [101,102]. The effectiveness of the Cloudburst Master Plan has been assessed through continuous monitoring of flood events and infrastructure performance.	SDG 3, SDG 4, SDG 6, SDG 8, SDG 9, SDG 11, SDG 13, SDG 15, SDG 16, SDG 17
		-	Green/Blue Infrastructure			-	Become the first carbon neutral capital in the world by 2025.			
		-	The city aims to realise 300 projects over 20 years.							

Table 3. Cont.

Technological Aspects								
	Key Technologies	Key Projects	Key Use Cases		Key Outcomes	Key Notes	Impacts	UN SDG's Linked
Tokyo (Japan) [79]	Smart Tokyo Initiative							
	5G, AI, VR, IoT, Data Analytics, Autonomous Systems, Robotics, Domotics, Inmotics.	Smart mobility, energy grids, public services.	Autonomous (air)-transportation, smart energy grids, real-time urban data management, digital public services.	- - - -	Streamlined and more efficient urban services, Better citizen engagement, Improved energy usage & reduced consumption, Enhanced public safety.	Focused on collaboration with startups to develop citizen focused, innovative services.	A survey indicated that 70% of citizens reported satisfaction with smart urban services, showing improved quality of life through technology use [75,103]. Data is gathered through user feedback mechanisms and service evaluations.	SDG 7, SDG 9, SDG 11, SDG 11,
Dubai (United Arab Emirates) [104,105]	Smart Dubai Initiative							
	AI, IoT, GIS, Big Data, Data Analytics, DT, Blockchain, BIM, CAD, AR/VR, Metaverse, Machine learning, 5G & 6G (R&D).	Smart Transportation Systems, Green Energy Projects.	- Air quality control, - Energy /Water consumption & management, - Transport & traffic behaviors, - Sandstorm monitoring, - Waste management - Air quality, - Building efficiency.	- - - - - - - -	Public services and citizen engagement, Real-life application, Monitoring urban growth, Sustainability benefits from environmental perspective management, Design & optimization of Infrastructure.	Extensive & immersive citizen engagement via 3D simulations & models for interaction & digital platforms.	Smart Dubai reported a 30% improvement in energy efficiency, supported by energy consumption analytics and reports from the Dubai Electricity and Water Authority [106]. Measurements are taken through real-time monitoring of consumption patterns.	SDG 3, SDG 6, SDG 7, SDG 9, SDG 11, SDG 13, SDG 13, SDG 15

Table 3. Cont.

Technological Aspects										
Key Technologies		Key Projects		Key Use Cases		Key Outcomes		Key Notes	Impacts	UN SDG's Linked
Toronto (Canada)	Quayside Smart Neighborhood [92]									
	AI, IoT, Robotics, BIM, Big Data, AR/VR, BIM.	-	Smart homes and infrastructure	-	Data-driven energy management, Smart waste and water systems, Sensors for real-time environmental monitoring, Public spaces with smart infrastructure.	-	Prototype of a hyperconnected urban neighborhood designed as a model to inspire other smart city projects around the world.	-	Visualization of infrastructure proposals through AR/VR. IoT devices and sensors collect real-time data to engage citizens in urban planning and sustainability efforts.	The neighborhood aims to achieve 15% lower carbon emissions through integrated smart technologies for energy and waste management, supported by ongoing environmental impact assessments and monitoring data [107,108].
New York (United States of America) [109]	The BIG U: NYC Community Spaces as Barriers for Flooding									
	BIM, GIS, AI, AR/VR, IoT.	-	Coastal flood risk mapping, Green infrastructure planning.	-	AR/VR used to simulate flood events and infrastructure impacts, IoT sensors for real-time environmental data.	-	Creation of flood control infrastructure. Increased participation rates in urban planning platforms. Implementation of real-time monitoring systems.	-	AR/VR allows citizens to visualize urban changes and flood protection; GIS and IoT support data-informed feedback processes.	Flood protection for more than 110,000 residents on the Lower East Side by creating 2000 new trees and renovating the East River Park with 8-foot elevations. In addition, retaining walls and movable barriers are being built in recreational areas, such as the Asser Levy Playground, contributing to the resilience of urban infrastructure [110].

Note: Blue, orange and gold designate the geographic regions for Europe, North America and Asia, respectively; light-blue, light-orange and light-gold designates the city scale and additionally in parentheses appears in italic the country.

5.1.3. Table 4—Analysis of Citizen Participatory Process

The smart and resilient cities projects in Helsinki, Copenhagen, Tokyo, Dubai, Toronto, and New York represent different approaches to citizen participation in urban planning, adapted to the socio-technological and cultural characteristics of each environment. Each project involves a combination of sectors and methodologies to maximize citizen involvement in urban decision-making.

The Helsinki 3D+ project in Helsinki uses digital twins and augmented reality as tools for citizen interaction. This approach focuses on providing citizens with access to interactive 3D models, with the aim of encouraging proposals for improvements in energy infrastructure and urban design. The open data methodology allows citizens to co-design aspects of their environment and better understand the implications of proposed projects. In this case, the use of digital visualization technologies facilitate informed participation in complex urban planning issues.

The Cloudburst project in Copenhagen adopts a climate resilience perspective through citizen participation in the planning of green infrastructure and flood mitigation measures. The complexity of this type of infrastructure requires a transdisciplinary approach, supported by GIS and interactive platforms that allow citizens to map and suggest locations for sustainable infrastructure. The high level of citizen participation in this context reflects a collaborative design model that engages adults from diverse academic and professional backgrounds in formulating solutions to environmental disasters.

In Tokyo, the Smart Tokyo Initiative emphasizes digital inclusion, in line with the concept of Society 5.0, by promoting citizen-centric smart services. The methodology is based on workshops and public consultations aimed at involving residents of different age groups and skill levels. Unlike Helsinki and Copenhagen, whose focus is on infrastructure and climate resilience, Tokyo prioritizes the development of accessible urban services to improve the quality of life and accessibility of technologies in a diverse urban context.

The Smart Dubai project in Dubai takes a holistic approach to sustainability and urban planning in the framework of the Happiness Agenda, with participatory activities including public consultations and 3D simulations. The mixed methodology combines qualitative feedback from citizens with real-time data analysis, which facilitates the development of urban infrastructures geared towards sustainability and social well-being. In contrast to European initiatives, which focus on specific infrastructure or resilience objectives, Dubai adopts a general urban development framework that seeks to integrate well-being into planning.

The Quayside project in Toronto emphasizes privacy and data governance, issues that have generated international debate. The methodology includes immersive design tools and citizen consultations focused on the transparency of sensor use and the protection of personal data. Unlike Tokyo and Dubai, which take an inclusive approach, Quayside prioritizes transparency as a key factor for citizen acceptance of emerging urban technologies, underlining the importance of privacy and security in the urban context.

Finally, in New York, The BIG U project focuses on resilient infrastructure for climate risk mitigation in response to the damage caused by Hurricane Sandy. Citizen participation is based on a community-centered design model, where public spaces serve as natural flood barriers, encouraging informed participatory planning. The co-creation model applied in this project aims to involve citizens with a high level of technological expertise and experience in strategic sectors, thus optimizing the capacity to respond to future disasters. This model contrasts with Copenhagen's transdisciplinary approach, which prioritizes green infrastructure as the main climate strategy.

Table 4. Aspects of the participatory citizen process of the case studies.

Citizen Participatory Process								
	Stakeholders	Participatory Context	Participatory Activities Carried Out	Methodological Approach	City Population	Number of Participating Citizens	Qualification of Citizens	
Helsinki (Finland) [95,96]	Helsinki 3D+							
	Helsinki City Government, Energy Companies, Constructors, Research Institutions, Citizens.	Citizens interact with the digital twin to propose improvements in energy and urban design, using AR/VR to explore new developments.	- Proposals on green and energy infrastructures, - Online platforms for feedback - Public forums on energy usage and smart city development - Workshops on digital city services.	An open-data approach enables co-design through digital platforms for citizen feedback, helping residents understand and engage with planned developments in their city. The detailed 3D models also support city planning decisions, addressing questions like, “Will a new development in this area block sunlight for the neighbouring building?”	5,563,970 (2022—estimate) [111]	Estimated 10,000 participants (through digital platforms and events).	Citizens from various sectors, including students, professionals, and energy experts.	
Copenhagen (Denmark) [112]	Cloudburst Initiative Copenhagen							
	Local Government & Public sector institution, Private sector, corporate, business Researchers, university Citizens or community groups/NGOs.	The process is driven by the need to generate profound change in a complex socio-technical system, which requires a transdisciplinary approach to its design.	Workshops, public consultations, and interactive mapping platforms where citizens could suggest green infrastructure and flood mitigation solutions.	Collaborative design and co-creation, using digital tools (GIS, interactive platforms) for flood risk communication and feedback.	659,352 (2024—estimate) [111]	Estimated 12,000+ (during 4 months in the last participatory event on 2023).	Varied: Mainly adults (ages 30–60), medium to advanced education level, with basic to medium technology skills.	

Table 4. Cont.

Citizen Participatory Process								
	Stakeholders	Participatory Context	Participatory Activities Carried Out	Methodological Approach	City Population		Number of Participating Citizens	Qualification of Citizens
Tokyo (Japan)	Smart Tokyo Initiative							
	Tokyo Metropolitan Government, startups, private tech companies, local communities & businesses, residents.	Aligned with Society 5.0, enhancing citizen engagement.	Workshops, public forums, online consultations.	Focusing on collaboration, inclusion, and citizen-centric smart services.	9,733,276 (2020—official) [111]	-	50 to 100 participants in each session in participatory pilot projects for initiatives, such as land use planning and transport management.	The initiative promotes participation from a diverse range of residents, ensuring that individuals of all ages and skill levels can engage with the digital city. This inclusivity fosters broader representation in urban planning.
						-	Approximately 300 citizens participate in the Tokyo Citizens’ Forum to discuss the urban future with the government.	

Table 4. Cont.

Citizen Participatory Process								
Stakeholders	Participatory Context	Participatory Activities Carried Out	Methodological Approach	City Population	Number of Participating Citizens	Qualification of Citizens		
Dubai (United Arab Emirates) [113]	Smart Dubai Initiative							
	Dubai Government, tech companies, academia, citizens.	Focus on urban planning, sustainability, and smart city development based on smart Dubai’s “Happiness Agenda”.	Co-design workshops, public consultations, 3D simulations, feedback collection through digital e-platform [89].	Mixed-method approach: qualitative citizen feedback + quantitative real-time data analysis.	3,355,900 (2019—estimate) [111]	- 14 million votes on satisfaction with public services in 2017 (Happiness meter). - 9000 attendees at the 2019 Future Blockchain Summit. - 65,000 candidates registered on Dubai Careers Portal in the first year (2017).	Majority adults (31–45 years), mid to high education level, intermediate to advanced tech skills.	

Table 4. Cont.

Citizen Participatory Process									
Stakeholders		Participatory Context		Participatory Activities Carried Out	Methodological Approach	City Population	Number of Participating Citizens	Qualification of Citizens	
Toronto (Canada) [114]	Quayside Smart Neighborhood								
	City, Province, and Government of Canada, Waterfront Toronto, Sidewalk Labs (Alphabet), Local Government, Real Estate Developers, Tech Sector, Citizens.	-	Concerns about privacy and data governance sparked robust debates.	-	Urban design proposals through immersive technologies, Citizen consultations on the use of sensors and privacy.	At the core of the participatory planning tools used by the Sidewalk Toronto project was the principle of community-driven development, guiding the overall approach to citizen engagement. Co-creation workshops & participatory design were main methods applied.	5,647,656 (2021—official) [111]	Estimated participation figures were 200 attendees for the drop-in sessions, 600 attendees for the public meetings, 200 responses to the online survey, and 34 written submissions, making an estimated total of 1034 total participations during the public consultation process.	Mixed demographics; range of educational backgrounds with varied knowledge of digital technology.

Table 4. Cont.

Citizen Participatory Process							
Stakeholders	Participatory Context	Participatory Activities Carried Out	Methodological Approach	City Population	Number of Participating Citizens	Qualification of Citizens	
New York (United States of America) [115]	The BIG U: NYC Community Spaces as Barriers for Flooding						
	NYC government, state and Federal agencies, HUD, local communities, NGOs.	Citizen support for The Big U arose after the severe damage New York experienced during Hurricane Sandy in 2012, raising awareness of the need for future disaster protection.	Participation through public consultations & workshops, community meetings, and online platforms.	The design should be community-driven, that means a citizen centric design process which involves co-creation and collaborative approaches.	8,258,035 (2023—official) [111]	30 community organizations taken part during process.	The demographic primarily includes higher-educated professionals in the business sector, with strong digital technology skills reflective of a tech-savvy urban environment.

Note: Blue, orange and gold designate the geographic regions for Europe, North America and Asia, respectively; light-blue, light-orange and light-gold designates the city scale and additionally in parentheses appears in italic the country.

5.2. Cross-Domain Analysis

5.2.1. Eco-Technological Intersections: Synergy of Ecology and Technology for Urban Environmental Challenges

The interplay between the ecological and the technological in the urban context is fundamental to addressing the growing environmental risks facing contemporary cities. Rapid urbanization, climate change and pressure on natural resources have led many metropolises to adopt innovative approaches that integrate advanced technologies with ecological considerations.

Helsinki faces a continental climate characterized by cold winters and hot summers. Temperatures have risen by approximately 2.4 °C in recent decades, leading to significant changes in weather patterns and an increased risk of flooding due to heavy rainfall and snowmelt [116]. Helsinki, through Helsinki 3D+, has implemented a 3D visualization platform for urban planning. This tool allows planners to integrate environmental data into decision-making, addressing risks such as urban flooding and the impact of climate change. According to the city's report, the ability to integrate ecological information into planning helps identify vulnerable areas and develop solutions that optimize energy efficiency and the use of urban space.

Copenhagen is exposed to extreme precipitation, which has increased by 60 percent since 1970. A report by the Danish Ministry of Climate, Energy and Utilities states that these heavy rainfall events are expected to increase in frequency and intensity due to climate change, posing a considerable challenge to the infrastructure of the city of Copenhagen, which is also affected by flooding due to its geography and rising sea levels [117]. The Cloudburst project focuses on water management through a sustainable drainage system that combines green infrastructure, such as parks and permeable surfaces, with real-time monitoring technologies. According to the Copenhagen Climate Adaptation Plan, this combination allows for more efficient storm management and rainwater harvesting, which reduces the risk of flooding and improves water quality in the urban environment [118].

Tokyo, one of the world's most densely populated cities, faces multiple climate risks, including typhoons and rising sea levels. Tokyo's average temperature has risen by about 1.2 °C since 1900, and sea level is expected to rise by 0.9 to 1.5 meters by 2100 [119,120]. The Smart Tokyo Initiative promotes a comprehensive approach that uses digitalization to address these challenges. With a focus on energy management and carbon emission reduction, Tokyo has developed monitoring systems that enable the efficient management of energy resources. This approach not only contributes to environmental sustainability but also improves the city's resilience to natural disasters, such as earthquakes and typhoons.

Dubai, located in a desert region, has temperatures that exceed 50 °C during the summer. A report by the UAE Ministry of Climate Change and Environment indicates that water scarcity is a critical challenge in the emirate, and climate change could reduce available water resources by 10 percent by 2030 [121,122]. The Smart Dubai Initiative integrates advanced technologies, such as IoT and data analytics, to efficiently manage water and energy. As mentioned in the city's strategy, these tools enable it to reduce carbon emissions and promote a more sustainable lifestyle, which is essential in a context where resource scarcity is a constant challenge.

Toronto, one of Canada's largest and most diverse cities, has experienced an increase in rainfall and flood risk, with warnings that heavy rainfall could increase by 20–30% by 2050, severely affecting the city's infrastructure and water quality [123]. In response to these challenges, the Quayside Smart Neighbourhood represents an innovative approach that integrates sustainable technologies into urban planning. This project focuses on water management and waste reduction, using smart technologies for collection and recycling. The integration of green spaces and renewable energy solutions not only improves the quality of life for residents but also promotes biodiversity and resilience to extreme weather events.

Finally, New York City faces rising sea levels and an increase in the frequency of intense storms. According to the New York City Panel on Climate Change, sea levels in the city are projected to rise by 1 to 2 feet by 2050, putting coastal communities at risk and

requiring significant adaptation of urban infrastructure [124]. The BIG U is a remarkable example of how infrastructure can be designed to address these risks. This project not only seeks to protect the city from flooding but also creates community spaces that foster social cohesion. The solutions implemented, which include physical barriers and drainage systems, reflect a deep understanding of how environmental risks can be mitigated through smart urban planning.

Analysis of the data collected in these initiatives reveals that most of the cities studied have adopted a proactive approach to environmental management and sustainable resource use. The implementation of smart and sustainable technologies is a common trend that allows cities not only to adapt to climate change but also to improve the quality of life of their inhabitants. Through the integration of green technologies and considerations, these metropolises are building a future that is more sustainable, resilient and adapted to the environmental challenges of the 21st century.

The intersection between the green and the technological is essential to address the environmental risks faced by modern cities. The case studies analyzed demonstrate that the adoption of advanced technologies, combined with a focus on environmental sustainability, enables these cities to manage their resources more efficiently and resiliently. This integrated approach not only responds to current challenges but also lays the foundation for a more sustainable and equitable future.

5.2.2. Socio-Ecological Intersections: Citizen–Technology Synergy for Resilient Cities

The impact of citizen participation on the outcomes of urban projects is significant, especially in those oriented towards sustainability and climate resilience. Co-creation and collaborative design of urban solutions, which include citizens' views and needs, not only increase the effectiveness of projects but also enhance community acceptance and ownership of initiatives. Active participation in urban planning promotes a sense of ownership and engagement among citizens [9].

In Helsinki, the active participation of citizens has generated clear results in terms of energy efficiency and urban optimization, evidenced by reduced energy consumption and improved urban planning. Citizens have not only provided feedback but have also played a key role in the co-creation of energy solutions. This interaction is facilitated through technologies that allow citizens to explore and visualize how new developments will affect their environment. Results from Helsinki demonstrate that citizen participation enhances urban planning, especially when immersive technologies enable a higher level of understanding and analysis by residents. Here, technology acts as a catalyst for more effective participatory decision-making [125].

The Cloudburst Initiative in Copenhagen has generated significant impacts in terms of climate resilience and flood mitigation. This has been possible thanks to a participatory approach where citizens have been able to propose solutions for green infrastructure and flood protection measures. Citizen feedback and collaborative platforms have been essential to tailor solutions to local needs, reflecting a strong social and environmental impact. The integration of digital consultation platforms with green infrastructure solutions has enabled citizens not only to contribute to urban planning but also to better prepare for climate challenges. In this case, the impact of participation translates into greater urban resilience [111].

In Tokyo, the Smart Tokyo Initiative seeks to integrate smart technologies into urban management, responding to a highly urbanized and resource-constrained environment. Citizen participation is essential to address environmental issues and optimize resource use. Through collaboration, innovative solutions are being developed that reflect the interaction between urban characteristics and ecological needs. This synergy enables citizens not only to participate but also to influence the formulation of policies that address climate change and sustainability [112].

In Dubai, the Smart Dubai Initiative promotes citizen participation in urban development. Dubai's biophysical environment, with its climatic extremes, poses unique challenges that require adaptive solutions. Through digital platforms, citizens are encouraged to share

their concerns and suggestions, which not only fosters a sense of ownership over projects but also reflects a commitment to sustainability. Decisions made in this context must consider the interactions between the built environment and natural ecosystems to achieve true resilience [113].

The case of Quayside in Toronto illustrates how concerns about privacy and data control can influence citizen participation and, thus, the viability of a project. Although planned as an innovative development that would integrate technology and sustainable design, community opposition led to its cancellation in 2020. This case highlights the importance of socio-ecological interactions, where perceptions of risk and public trust are critical to the success of urban initiatives. Relationships between citizens, technology, and the urban environment are crucial to effectively address ecological challenges [91,92].

The BIG U project in New York, implemented in the aftermath of Hurricane Sandy, illustrates how citizen participation has been instrumental in building flood control infrastructure and creating community spaces that act as natural barriers. The use of technologies such as AR and VR to simulate flooding, along with citizen feedback, has facilitated more resilient urban planning and greater transparency in the decision-making process. In this case, AR/VR technology has been key to increasing public awareness and preparing citizens for future climate contingencies, while direct participation has influenced the design of critical infrastructure. This demonstrates how technological tools can foster a more informed and engaged community, transforming perceptions of climate risks and improving disaster preparedness and response [126].

Taken together, these case studies highlight that the effectiveness of urban initiatives depends on the interaction between citizens and the biological and physical aspects of the environment. Collaboration and the use of appropriate technologies are key to fostering greater resilience and sustainability in urban planning, ensuring that urban solutions not only address current needs but also adapt to future ecological challenges.

5.2.3. Socio-Technological Intersections: Challenges and Diversity of Participation Models in the Smart Cities Era

Social–technological interaction in urban initiatives reveals how technological infrastructures influence forms of citizen participation and the extent to which these technologies facilitate inclusive and equitable access to urban governance. The analysis of the cases highlights the diversity in the participatory and technological approaches adopted by different cities, reflecting their specific social, political, and technological contexts.

In Helsinki, the 3D+ initiative stands out for integrating advanced technologies such as 3D modeling, AR/VR and IoT into urban planning processes. This combination enables citizens to visualize infrastructure proposals and actively participate in the creation of sustainable solutions. The use of interactive platforms and open data has stimulated the participation of a diverse population, including people with energy and planning expertise. Here, technology acts as a primary enabler of participation, fostering greater citizen understanding and engagement [127,128].

On the other hand, in Copenhagen, the Cloudburst Initiative demonstrates a strong correlation between the adoption of technologies such as GIS and BIM and citizen participation. Flood risk modeling and green infrastructure have involved approximately 2% of the population in the co-creation of sustainable solutions through interactive platforms and workshops. In this case, technology not only enhances urban resilience but also provides citizens with the necessary educational tools to intervene in urban planning [129,130].

In Dubai, the Smart Dubai Initiative combines advanced technologies such as AI, Blockchain, and IoT with a participatory approach based on the Happiness Agenda. However, citizen participation tends to focus more on feedback through 3D simulations and digital platforms, indicating a more centralized approach. Although Dubai employs a wide range of advanced technologies for urban management, the level of citizen participation is less inclusive compared to other cities such as Helsinki and Copenhagen. This suggests that technology in Dubai is used more to optimize the urban environment than to empower

citizens to co-create the city, which may result in a more technocratic model than one that encourages active, deliberative participation [131].

In the case of Tokyo, although the city embraces cutting-edge technologies such as 5G and robotics, citizen participation is more controlled and less co-creative. Key decisions are mainly driven by local authorities and the private sector, limiting direct interaction in day-to-day urban planning. This approach prioritizes technological efficiency over citizen co-creation, which can result in a sense of exclusion among citizens and a possible distrust of institutions [132,133].

The Toronto case, Quayside Smart Neighbourhood, illustrates how concerns about privacy and data control can affect the implementation of urban projects. Although the initiative aimed to integrate advanced technology into urban design, a lack of effective participation and community skepticism led to its cancellation in 2020. This result highlights the importance of trust and citizen engagement in the success of such projects and how lack of inclusion can have a negative impact on urban initiatives [9,134].

In New York, the Big U initiative, created in response to Hurricane Sandy, has been instrumental in developing flood control infrastructure and creating community spaces that act as natural barriers. The implementation of technologies such as AR/VR to simulate flooding has facilitated more resilient urban planning and improved transparency in the decision-making process. In this case, the technology not only raises public awareness of climate risks but has also transformed citizen participation, allowing residents to contribute to the design of critical infrastructure and prepare for future climate contingencies [109].

The analysis of these cases shows that the relationship between technology and citizen participation in urban projects is complex and multifaceted. While some cities, such as Helsinki and Copenhagen, show a collaborative approach that empowers citizens, others, such as Dubai and Tokyo, tend towards a more centralized and technocratic model. This diversity in approaches underlines the need to adapt technological and participatory strategies to the specific realities of each city to achieve more inclusive and resilient urban development.

6. Discussion

The findings of this research provide a comprehensive overview of the interaction between digital technologies, citizen participation and sustainability in the context of six iconic cities: Helsinki, Copenhagen, Tokyo, Dubai, New York, and Toronto. These results are contrasted with previous studies that underline the growing importance of digitalization in urban planning. For example, Abdirahim Bashiir [135] and Mehmood et al. [136] have shown that the implementation of emerging technologies, such as IoT and DTs, improves the efficiency of urban resource management and encourages greater citizen engagement in decision-making.

6.1. Research Variables

6.1.1. Emerging Technologies

The research identified that the implementation of technologies such as 5G and digital platforms has enabled greater connectivity and access to information for citizens. This translates into increased participation in urban sustainability initiatives. The cities analyzed show that the adoption of these technologies can lead to an increase in the effectiveness of sustainability policies, highlighting the need for a robust technological infrastructure as a fundamental pillar for sustainable development [128].

6.1.2. Commitment to Sustainability

The findings also reveal a strong correlation between cities' commitment to the SDGs and the level of citizen engagement. Cities that have integrated sustainability goals into their urban planning, such as Toronto and New York, have higher rates of citizen involvement in sustainability projects. This highlights the importance of urban policies that promote not only digitization but also the active inclusion of citizens in the process [137].

6.1.3. Models of Citizen Participation

When analyzing the various citizen participation strategies, two predominant approaches are identified: the collaborative model and the technocratic model. In Copenhagen and Helsinki, for example, a more collaborative approach was observed, where citizens are actively involved in urban policy-making. This approach has proven to be effective in increasing trust between citizens and local authorities [138]. In contrast, in cities such as Dubai and Tokyo, the techno-democratic model predominates, with citizen participation limited to feedback on already defined projects, which can limit the effectiveness of participation [139].

6.2. Comparison of Results

The comparison of the six cities highlights how the integration of emerging technologies and participatory methodologies can transform urban and environmental planning, promoting broader citizen inclusion and collaboration. Copenhagen and Helsinki stand out for their approaches to sustainability and resilience, prioritizing green infrastructure and Nature-based Solutions (NBS). Copenhagen, through its Cloudburst initiative, uses technologies such as GIS and BIM to map flood risks and co-design solutions with citizens. This approach demonstrates how participatory governance, supported by digital tools, can improve the response to climate challenges and strengthen urban resilience. Helsinki, with its Helsinki 3D+ project, encourages citizen collaboration through the use of open platforms and AR/VR technology, enabling citizens to participate in the co-creation of urban projects.

In contrast, Dubai and Tokyo are prime examples of cities heavily focused on digital infrastructure and the integration of advanced technologies like IoT, AI, and DTs to drive urban efficiency and position themselves as smart city frontrunners. Their smart city agendas prioritize urban automation, energy optimization, and interactive citizen engagement through technologies like AR/VR. However, both cities face notable climate-related risks, which increasingly shape their urban strategies. Dubai experiences extreme temperatures and rising drought conditions, with projections indicating an intensified frequency of dust and sandstorms that impact both public health and operational continuity [123,140–142]. Tokyo, meanwhile, encounters escalating risks from extreme rainfall events, typhoons, and urban heat, which are projected to increase under future climate scenarios [143,144]. Consequently, these digital initiatives are not only pathways to innovation but also essential elements in building resilient infrastructure that can better manage and mitigate these evolving climate impacts.

Finally, Toronto and New York offer contrasting perspectives on data governance and public trust in smart city projects. The Quayside project in Toronto, despite its innovative approach, was unable to move forward due to data privacy issues and lack of citizen trust, highlighting the importance of strong data governance in urban planning initiatives. In contrast, New York has prioritized inclusiveness and transparency with visual technologies to encourage citizen participation in the planning process, underlining that the success of smart cities depends both on the technology used and on governance structures that ensure citizen trust and engagement.

To facilitate a clear understanding of the results, a summary highlighting the main findings for each city in relation to the research variables is presented (Table 5).

Table 5. Summary table.

City	Participation Model	Key Technologies
Helsinki	Collaborative	GIS, Laser Scanning, Oblique photogrammetry, LIDAR, CAD, DT, 3D City Models, IoT, Smart Energy Systems, AI.
Copenhagen	Collaborative	AI, IoT, GIS, BIM, VR, digital community engagement platform, GPR.
Tokyo	Technocratic	5G, AI, VR, IoT, Data Analytics, Autonomous Systems, Robotics, Domotics, Inmotics.
Dubai	Technocratic	AI, IoT, GIS, Big Data, Data Analytics, DT, Block-chain, BIM, CAD, AR/VR, Metaverse, Machine learning, 5G & 6G (R&D).
Toronto	Collaborative	AI, IoT, Robotics, BIM, Big Data, AR/VR, BIM.
New York	Collaborative	BIM, GIS, AI, AR/VR, IoT.

7. Conclusions

This study has addressed the research question of how the integration of emerging technologies impacts sustainability and urban governance in six iconic cities: Helsinki, Copenhagen, Tokyo, Dubai, New York, and Toronto. The main objective has been to assess the tensions and challenges faced by these cities in the context of digitalization and their relationship to sustainable development.

The findings of this study highlight several key tensions and challenges those cities face when integrating emerging technologies with sustainability and urban governance. One of the most obvious issues is the dichotomy between digitalization and sustainability. Cities such as Dubai and Tokyo, which do not immediately face the most severe effects of climate change, tend to focus on deep digital transformation, using advanced technologies to improve their infrastructure and attract global investment. This approach demonstrates a prioritization of economic growth and technological competitiveness over environmental strategies. In contrast, cities such as Copenhagen and Helsinki have adopted a sustainability-focused approach, investing in green infrastructure and resilient solutions that, while requiring less budget compared to technological infrastructure, offer greater protection from climate hazards. This contrast underlines the importance of considering local priorities and vulnerabilities when defining urban agendas.

A second critical issue is data governance and privacy in the implementation of advanced technologies. The analysis reveals that as smart cities collect and process massive volumes of data, transparent and accountable management of this information becomes crucial. The failure of the Toronto smart city project illustrates how the lack of sound data governance strategies can compromise even the most technologically advanced projects. Without a clear structure to ensure privacy and transparency in the collection and use of data, any advances in urban infrastructure can be undermined by public distrust. This highlights the need to develop regulatory frameworks that regulate the use of emerging technologies in an ethical and fair manner.

In terms of citizen engagement, the study highlights those cities with a strong private sector presence, such as Dubai and Tokyo, which tend to focus on technological innovation and data optimization. These cities seek to optimize efficiency and global competitiveness by adopting digital solutions. However, cities with stronger government leadership, such as Helsinki and Copenhagen, favor collaborative and sustainability-focused processes, where the focus is on involving citizens in urban decision-making through inclusive participatory platforms. This distinction suggests that cities should not only adopt digital participation platforms but also ensure that these tools are accessible and equitable so that all sectors of society can participate meaningfully.

Given the strong urban focus of this study, it is essential to acknowledge that digital technologies could play a crucial role in unlocking opportunities for more remote and underserved areas. Integrating technology in these regions can facilitate improved connectivity and access to resources, thereby promoting more inclusive urban–rural dynamics. Digital solutions can empower residents in remote areas by providing them with access to information, services, and platforms for civic engagement, thus bridging the urban–rural divide.

Furthermore, the promotion of inclusive participation is vital to ensuring that all community members, especially those in marginalized areas, have a voice in decision-making processes. This is particularly relevant in urban contexts where private sector interests may dominate. Cities must strive to create participatory platforms that not only encourage citizen engagement but also prioritize the needs of vulnerable populations. This requires a commitment to equitable access to these platforms, ensuring that socio-economic barriers do not hinder participation.

Finally, it underlines the need for technology strategies to be adapted to the local contexts of each city. While Dubai and Tokyo position themselves as global hubs through the mass adoption of emerging technologies, Helsinki and Copenhagen prioritize long-term resilience to climate challenges through sustainable solutions. This reinforces the idea that there is no one-size-fits-all solution for urban planning and that cities must

develop tailored approaches that consider not only technological innovations but also their specific geographic, socio-economic, and environmental characteristics. The design of urban solutions must be based on a thorough understanding of local needs and the creation of flexible tools that can evolve with changes in the global and local context.

This study reflects that the adoption of emerging technologies in urban planning is not simply a matter of efficiency and modernization but must be guided by principles of sustainability, ethical governance, and inclusive citizen participation. In light of the Global North focus of this paper, it is crucial to ensure that the benefits of digital technologies are accessible to all, including those in remote and disadvantaged areas. By recognizing the unique challenges faced by these communities, urban planners can leverage technology not only to enhance urban living but also to promote equity and justice across different regions.

This research contributes to the field by providing a nuanced understanding of the interplay between emerging technologies and sustainability in urban governance. It highlights the importance of context-specific strategies that prioritize ethical governance, citizen engagement, and the resilience of urban systems. However, the study is not without limitations. The focus on six cities may not capture the full spectrum of urban experiences worldwide. It would also be interesting to analyze the dynamics of the Global South, where different socio-economic and environmental challenges exist. Further research is needed to explore these dynamics in diverse contexts.

Ultimately, the cities of the future will not only be defined by their capacity to integrate new technologies but also by their ability to balance digital innovation with environmental protection and social justice, ensuring truly sustainable and equitable urban development.

8. Recommendations

The recommendations derived from this study underline the need for a holistic and balanced approach to the development of smart cities. First, balancing technology and sustainability is a key challenge. While investment in emerging technologies is crucial to optimize urban management and improve infrastructure, it is equally important that these investments do not sacrifice solutions aimed at climate resilience and long-term community well-being. Geels [145] argues that success in the transition to more sustainable cities does not depend solely on digitization but on a holistic approach that considers both social and environmental sustainability. In this sense, cities should aim for planning that integrates both dimensions, ensuring that technological innovation and environmental protection work in synergy.

Secondly, it underlines the importance of strengthening data governance. Citizen trust in smart city projects will depend to a large extent on how the personal information collected is handled [146–148]. To avoid distrust, as in failed cases such as Toronto, clear and transparent privacy policies are essential. According to Kitchin [149], data governance should include regular audits and citizen participation mechanisms that promote transparency in data management. These measures not only protect citizens' privacy by ensuring data is handled responsibly but also build a participatory culture where citizens feel invested in the decision-making process. This, in turn, fosters ethical and accountable governance, bolstering the legitimacy of urban projects and encouraging sustained public support.

Furthermore, establishing a regulatory framework for the responsible use of data is paramount. This framework should be developed collaboratively, involving stakeholders from various sectors, including government agencies, private sector leaders, civil society organizations and international organizations. Local governments should take the lead in spearheading this initiative, as they are closest to the citizens and can tailor regulations to meet community needs. Moreover, engaging citizens in the formulation of these regulations is crucial, as it ensures that their voices are heard and their concerns are addressed. This collective approach not only enhances accountability but also reinforces the legitimacy of data governance frameworks, thereby fostering a more sustainable and trusted, smart city environment.

Promoting inclusive participation is another key pillar. Digitalization can, in some cases, exacerbate existing inequalities if measures are not implemented to ensure that

all citizens, regardless of their level of digital literacy or technological skills, have access to participation platforms. Evans et al. [150] suggest that inclusive platforms should be designed with the diversity of the population in mind, ensuring that marginalized groups or those with less access to technology are not excluded from decision-making processes. Diverse participation is key for technology solutions to be truly representative of citizens' needs and aspirations.

Finally, cities are recommended to adopt an adaptive approach that responds to both local challenges and global changes. Cities located in areas vulnerable to climate change should prioritize resilience solutions, while those less affected by these risks, such as Dubai and Tokyo, can focus on developing digital infrastructures that boost their competitiveness in the global economy. However, as Bulkeley [151,152] stresses, urban development cannot follow a one-size-fits-all approach; solutions must be tailored to the geographic, socio-economic, and cultural characteristics of each city.

Ultimately, the future of smart cities does not depend solely on the mass adoption of technology or an exclusive focus on sustainability. Rather, their success lies in the ability to integrate both visions in a balanced way, using technology not as an end but as a means to improve quality of life, promote urban efficiency and, at the same time, ensure environmental protection. Cities that manage to strike this balance will most likely be the ones that lead the transformation toward a smarter, more inclusive, and livable future.

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References

1. Brenner, N.; Schmid, C. Towards a new epistemology of the urban? *City* **2015**, *19*, 151–182. [\[CrossRef\]](#)
2. Satterthwaite, D.; McGranahan, G.; Tacoli, C. Urbanization and its implications for food and farming. *Philos. Trans. R. Soc. B Biol. Sci.* **2010**, *365*, 2809–2820. [\[CrossRef\]](#) [\[PubMed\]](#)
3. Massey, D. Globalisation: What does it mean for geography? *Geography* **2002**, *87*, 293–296. [\[CrossRef\]](#)
4. Hodson, M.; Marvin, S. Urbanism in the anthropocene: Ecological urbanism or premium ecological enclaves? *City* **2010**, *14*, 298–313. [\[CrossRef\]](#)
5. UN-Habitat. *The World Cities Report 2016: Urbanization and Development: Emerging Futures*; United Nations Human Settlements Programme: Nairobi, Kenya, 2016.
6. Berigüete Alcántara, F.; R. Cantalapiedra, I.; Palumbo Fernández, M.; Maseck, T. ¿Cómo medir el impacto de las iniciativas ciudadanas en la sostenibilidad urbana? *ACE Archit. City Environ.* **2022**, *17*, 10413. [\[CrossRef\]](#)
7. Graham, S.; Simon, M. *Splintering Urbanism: Networked Infrastructures, Technological Mobilities and the Urban Condition*, 1st ed.; Routledge: London, UK, 2001; ISBN 9780415189651.
8. Arnstein, S.R. A ladder of citizen participation. *J. Am. Inst. Plann.* **1969**, *35*, 216–224. [\[CrossRef\]](#)
9. Innes, J.E.; Booher, D.E. Reframing public participation: Strategies for the 21st century. *Plan. Theory Pract.* **2004**, *5*, 419–436. [\[CrossRef\]](#)
10. Berigüete, F.E.; Rodríguez Cantalapiedra, I.; Palumbo, M.; Maseck, T. Collective Intelligence to Co-Create the Cities of the Future: Proposal of an Evaluation Tool for Citizen Initiatives. *Sustainability* **2023**, *15*, 7956. [\[CrossRef\]](#)
11. Simonofski, A.; Asensio, E.S.; Wautelet, Y. Citizen participation in the design of smart cities: Methods and management framework. In *Smart Cities: Issues and Challenges*; Visvizi, A., Lytras, M.D., Eds.; Elsevier: Amsterdam, The Netherlands, 2019; pp. 47–62, ISBN 978-0-12-816639-0.

12. Batty, M. *Inventing Future Cities*; The MIT Press: Cambridge, MA, USA, 2018; ISBN 9780262038959.
13. Friedmann, J. *Insurgencies: Essays in Planning Theory*, 1st ed.; Routledge: London, UK, 2011; ISBN 9780203832110.
14. Monkelbaan, J. *Governance for the Sustainable Development Goals: Exploring an Integrative Framework of Theories, Tools, and Competencies*; Springer: Singapore, 2019; ISBN 978-981-13-4425-1.
15. Meuleman, L. Public administration and governance for the sdgs: Navigating between change and stability. *Sustainability* **2021**, *13*, 5914. [\[CrossRef\]](#)
16. Tartia, J.; Härmäläinen, M. Co-creation Processes and Urban Digital Twins in Sustainable and Smart Urban District Development—Case Kera District in Espoo, Finland. *Open Res. Eur.* **2024**, *4*, 130. [\[CrossRef\]](#)
17. Costa, D.G.; Bittencourt, J.C.N.; Oliveira, F.; Just Peixoto, J.P.; Jesus, T.C. Achieving Sustainable Smart Cities through Geospatial Data-Driven Approaches. *Sustainability* **2024**, *16*, 640. [\[CrossRef\]](#)
18. Cortés-Cediel, M.E.; Cantador, I.; Bolívar, M.P.R. Analyzing Citizen Participation and Engagement in European Smart Cities. *Soc. Sci. Comput. Rev.* **2021**, *39*, 592–626. [\[CrossRef\]](#)
19. Nurminen, V.; Rossi, S.; Rinne, T.; Kyttä, M. How has digital participatory mapping influenced urban planning: Views from nine planning cases from Finland. *Comput. Environ. Urban Syst.* **2024**, *112*, 102152. [\[CrossRef\]](#)
20. Wallin, S.; Horelli, L.; Saad-Sulonen, J. (Eds.) *Digital Tools in Participatory Planning*; Aalto University: Espoo, Finland, 2010; ISBN 9789526032597.
21. Castells, M. *The Rise of the Network Society*, 2nd ed.; Wiley-Blackwell: Oxford, UK, 2009; ISBN 9781444319514.
22. Beriguete Alcántara, F.E.; De Los Santos Melo, A.; Santos Castillos, J.S. Geospatial Insights: Harnessing GIS for Innovation in Architectural and Building Engineering Education. In *Teaching Innovation in Architecture and Building Engineering*; Bienvenido-Huertas, D., de la Hoz-Torres, M.L., Aguilar Aguilera, A.J., Eds.; Springer: Cham, Switzerland, 2024; pp. 257–273, ISBN 9783031596445. [\[CrossRef\]](#)
23. De Los Santos Melo, A.; Beriguete Alcántara, F.E. Maximizing Learning Potential: Embracing the Power of Digital Twins in Architectural and Construction Education of the Twenty-first Century. In *Teaching Innovation in Architecture and Building Engineering*; Bienvenido-Huertas, D., de la Hoz-Torres, M.L., Aguilar Aguilera, A.J., Eds.; Springer: Cham, Switzerland, 2024; pp. 477–493, ISBN 9783031596445. [\[CrossRef\]](#)
24. Harrison, C.; Donnelly, I.A. A Theory of Smart Cities. In Proceedings of the 55th Annual Meeting of the ISSS, Hull, UK, 17–22 July 2011; Volume 55, pp. 1–15.
25. Allam, Z.; Sharifi, A.; Bibri, S.E.; Chabaud, D. Emerging Trends and Knowledge Structures of Smart Urban Governance. *Sustainability* **2022**, *14*, 5275. [\[CrossRef\]](#)
26. Kaiser, Z.R.M.A. Smart governance for smart cities and nations. *J. Econ. Technol.* **2024**, *2*, 216–234. [\[CrossRef\]](#)
27. Hollands, R.G. Will the real smart city please stand up? Intelligent, progressive or entrepreneurial? *City* **2008**, *12*, 303–320. [\[CrossRef\]](#)
28. Batty, M.; Axhausen, K.W.; Giannotti, F.; Pozdnoukhov, A.; Bazzani, A.; Wachowicz, M.; Ouzounis, G.; Portugali, Y. Smart cities of the future. *Eur. Phys. J. Spec. Top.* **2012**, *214*, 481–518. [\[CrossRef\]](#)
29. Batty, M. Artificial intelligence and smart cities. *Environ. Plan. B Urban Anal. City Sci.* **2018**, *45*, 3–6. [\[CrossRef\]](#)
30. Nani, A.; Deschamps, L. Quayside: Revitalizing the Toronto Smart City Project. Available online: <https://www.iveybusinessreview.ca/magazine/articles/the-key-to-quayside-revitalizing-the-toronto-smart-city-project> (accessed on 22 October 2024).
31. Fuchs, C. *Social Media: A Critical Introduction*, 3rd ed.; SAGE Publishing Ltd.: London, UK, 2021; ISBN 978-1529752748.
32. Ferré-Bigorra, J.; Casals, M.; Gangoellis, M. The adoption of urban digital twins. *Cities* **2022**, *131*, 103905. [\[CrossRef\]](#)
33. Maccani, G.; Donnellan, B.; Helfert, M. A comprehensive framework for smart cities. In Proceedings of the 2nd International Conference on Smart Grids and Green IT Systems (SMARTGREENS-2013), Aachen, Germany, 9–10 May 2013; Volume 1, pp. 53–63. [\[CrossRef\]](#)
34. Hashem, I.A.T.; Chang, V.; Anuar, N.B.; Adewole, K.; Yaqoob, I.; Gani, A.; Ahmed, E.; Chiroma, H. The role of big data in smart city. *Int. J. Inf. Manag.* **2016**, *36*, 748–758. [\[CrossRef\]](#)
35. Glaessgen, E.H.; Stargel, D.S. The digital twin paradigm for future NASA and U.S. air force vehicles. In Proceedings of the 53rd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, Honolulu, HI, USA, 23–26 April 2012; pp. 1–14.
36. Fuller, A.; Fan, Z.; Day, C.; Barlow, C. Digital Twin: Enabling Technologies, Challenges and Open Research. *IEEE Access* **2020**, *8*, 108952–108971. [\[CrossRef\]](#)
37. Attaran, M.; Celik, B.G. Digital Twin: Benefits, use cases, challenges, and opportunities. *Decis. Anal. J.* **2023**, *6*, 100165. [\[CrossRef\]](#)
38. Soori, M.; Arezoo, B.; Dastres, R. Digital twin for smart manufacturing, A review. *Sustain. Manuf. Serv. Econ.* **2023**, *2*, 100017. [\[CrossRef\]](#)
39. Sharma, A.; Kosasih, E.; Zhang, J.; Brintrup, A.; Calinescu, A. Digital Twins: State of the art theory and practice, challenges, and open research questions. *J. Ind. Inf. Integr.* **2022**, *30*, 100383. [\[CrossRef\]](#)
40. Deng, T.; Zhang, K.; Shen, Z.J. (Max) A systematic review of a digital twin city: A new pattern of urban governance toward smart cities. *J. Manag. Sci. Eng.* **2021**, *6*, 125–134. [\[CrossRef\]](#)
41. Vilcea, C.; Şoşea, C. A GIS-based analysis of the urban green space accessibility in Craiova city, Romania. *Geogr. Tidsskr. J. Geogr.* **2020**, *120*, 19–34. [\[CrossRef\]](#)

42. National Research Council. *GIS for Housing and Urban Development*; The National Academies Press: Washington, DC, USA, 2003.
43. Longley, P.A.; Goodchild, M.; Maguire, J.; Rhind, D.W. *Geographic Information Systems & Science*, 3rd ed.; John Wiley & Sons Ltd.: Hoboken, NJ, USA, 2010; ISBN 978-0470721445.
44. Harris, T.M.; Elmes, G.A. The application of GIS in urban and regional planning: A review of the North American experience. *Appl. Geogr.* **1993**, *13*, 9–27. [\[CrossRef\]](#)
45. Simpson, D.M. Virtual reality and urban simulation in planning: A literature review and topical bibliography. *J. Plan. Lit.* **2001**, *15*, 359–372. [\[CrossRef\]](#)
46. Parisi, T. *Learning Virtual Reality: Developing Immersive Experiences and Applications for Desktop, Web, and Mobile*; O'Reilly Media: Sebastopol, CA, USA, 2015; ISBN 1491922834.
47. Jiang, L.; Maffei, L.; Masullo, M. Developing an online Virtual Reality application for e-participation in urban sound planning. In *Proceeding of EuroRegio 2016*, Porto, Portugal, 13–15 June 2016; pp. 1–10.
48. Nguyen, M.-T.; Nguyen, H.-K.; Vo-Lam, K.-D.; Nguyen, X.-G.; Tran, M.-T. Applying Virtual Reality in City Planning. In *Proceedings of the Virtual, Augmented and Mixed Reality*; Lackey, S., Shumaker, R., Eds.; Springer: Cham, Switzerland, 2016; pp. 724–735. [\[CrossRef\]](#)
49. Tang, L.; Chen, C.; Tang, S.; Wu, Z.; Trofimova, P. Building Information Modeling and Building Performance Optimization. In *Encyclopedia of Sustainable Technologies*; Abraham, M.A., Ed.; Elsevier: Oxford, UK, 2017; pp. 311–320, ISBN 978-0-12-804792-7.
50. Succar, B. Building information modelling framework: A research and delivery foundation for industry stakeholders. *Autom. Constr.* **2009**, *18*, 357–375. [\[CrossRef\]](#)
51. Volk, R.; Stengel, J.; Schultmann, F. Building Information Modeling (BIM) for existing buildings—Literature review and future needs. *Autom. Constr.* **2014**, *38*, 109–127. [\[CrossRef\]](#)
52. Tang, S.; Shelden, D.R.; Eastman, C.M.; Pishdad-Bozorgi, P.; Gao, X. A review of building information modeling (BIM) and the internet of things (IoT) devices integration: Present status and future trends. *Autom. Constr.* **2019**, *101*, 127–139. [\[CrossRef\]](#)
53. Eastman, C.; Teicholz, P.; Sacks, R.; Liston, K. *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*; John Wiley & Sons Ltd.: Hoboken, NJ, USA, 2011; ISBN 9780470541371.
54. Goodchild, M.F. Citizens as sensors: The world of volunteered geography. *GeoJournal* **2007**, *69*, 211–221. [\[CrossRef\]](#)
55. Gil, O.; Cortés-Cediel, M.E.; Cantador, I. Citizen Participation and the Rise of Digital Media Platforms in Smart Governance and Smart Cities. In *Research Anthology on Citizen Engagement and Activism for Social Change*, 2nd ed.; Information Resources Management Association: Hershey PA, USA, 2022; pp. 1186–1202, ISBN 9781668437063.
56. Nabatchi, T.; Amsler, L.B. Direct Public Engagement in Local Government. *Am. Rev. Public Adm.* **2014**, *44*, 635–885. [\[CrossRef\]](#)
57. Berigüete, F.E.; Cantalapiedra, I.R.; Palumbo, M.; Masseck, T. Sustainability Impact Unveiled: Validating a Multi- criteria tool for Assessing Citizen Initiatives. *Int. Multidiscip. J. Soc. Sci.* **2024**, *95*, 104629. [\[CrossRef\]](#)
58. Brabham, D.C. Crowdsourcing the Public Participation Process for Planning Projects. *Plan. Theory* **2009**, *8*, 242–262. [\[CrossRef\]](#)
59. Dramstad, W.E.; Fjellstad, W.J. Landscapes: Bridging the gaps between science, policy and people. *Landsc. Urban Plan.* **2011**, *100*, 330–332. [\[CrossRef\]](#)
60. Borges, J.; Zyngier, C. Crowdsourcing. A citizen participation challenge. *TeMA J. Land Use Mobil. Environ.* **2014**, 87–96. [\[CrossRef\]](#)
61. Beck, D.; Storopoli, J.E.; Vigoda-Gadot, E. A Qualitative Meta-Analysis of the Stakeholder Types in Urban Management. In *Proceedings of the European Urban Research Association 2023 Conference*, Reykjavik, Iceland, 22–26 June 2023; p. 23.
62. Kokx, A.; van Kempen, R. Dutch urban governance: Multi-level or multi-scalar? *Eur. Urban Reg. Stud.* **2010**, *17*, 355–369. [\[CrossRef\]](#)
63. Leck, H.; Simon, D. Fostering Multiscalar Collaboration and Co-operation for Effective Governance of Climate Change Adaptation. *Urban Stud.* **2013**, *50*, 1221–1238. [\[CrossRef\]](#)
64. IESE Business School. IESE Cities in Motion Index 2016. Available online: http://www.iese.edu/research/pdfs/ST-0396-E.pdf?_ga=1.13056181.367859667.1479064155 (accessed on 18 October 2024).
65. IESE Business School. Cities in Motion Index 2024. 2024. Available online: <https://citiesinmotion.iese.edu/indicecim/index.eng.html> (accessed on 18 October 2024).
66. World Competitiveness Center—IMD Business School. IMD Smart City Index 2024. 2024. Available online: https://imd.widen.net/content/uurdpo9mt3/pdf/20240412-SmartCityIndex-2024-Full-Report_4.pdf (accessed on 18 October 2024).
67. World Competitiveness Center—IMD Business School. Smart City Observatory. 2024. Available online: <https://www.imd.org/smart-city-observatory/home/rankings/> (accessed on 18 October 2024).
68. Institute for Urban Strategies (IUS). The Global Power City Index 2023. 2023. Available online: <https://mori-m-foundation.or.jp/ius/gpci/index.shtml> (accessed on 18 October 2024).
69. Institute for Urban Strategies (IUS). What Is the GPCI? Available online: <https://mori-m-foundation.or.jp/english/ius2/gpci2/index.shtml> (accessed on 20 October 2024).
70. Oxford Economics. Oxford Economics Global Cities Index 2024. 2024. Available online: <https://www.oxfordeconomics.com> (accessed on 18 October 2024).
71. Oxford Economics. Global Cities Index. 2024. Available online: <https://www.oxfordeconomics.com/global-cities-index/> (accessed on 18 October 2024).

72. Global innovation agency 2thinknow. The Innovation Cities™ Index 2022–2023: Global 500 World's Most Innovative Cities. Available online: <https://innovation-cities.com/worlds-most-innovative-cities-2022-2023-city-rankings/26453/> (accessed on 18 October 2024).
73. Graham, S. *Telecommunications and the City: Electronic Spaces, Urban Places*, 1st ed.; Routledge: London, UK, 1995; ISBN 978-0415119030.
74. Salles, A.; Salati, M.; Bragança, L. Analyzing the Feasibility of Integrating Urban Sustainability Assessment Indicators with City Information Modelling (CIM). *Appl. Syst. Innov.* **2023**, *6*, 45. [CrossRef]
75. Isi Lab. 2022 Smart Cities Index Report: Analysis of 31 Smart Cities. 2022. Available online: <https://smartcitiesindex.org/smartcitiesindexreport2022> (accessed on 20 October 2024).
76. Zhou, W.; Pickett, S.T.A.; McPhearson, T. Conceptual frameworks facilitate integration for transdisciplinary urban science. *NPJ Urban Sustain.* **2021**, *1*, 1. [CrossRef]
77. Suomisto, J. Helsinki 3D + Urban Digital Twins. 2021, p. 21. Available online: https://georomandie.com/2021/storage/app/media/presentations/parrallele_E/JRG2021_SessionE_Suomisto.pdf (accessed on 28 October 2024).
78. Whitesides, A.; Clingen, K. Copenhagen Cloudburst Plan. Harvard University. 2023. Available online: <https://www.gsd.harvard.edu/project/copenhagen-cloudburst-plan/> (accessed on 28 October 2024).
79. Manabu, M. Smart Tokyo Implementation Strategy. For Realization of a Tokyo Version of Society 5.0. 2020. Available online: <https://fpj.jp/wp/wp-content/uploads/2020/02/7804158048eebdac90be2faa07ef31c.pdf> (accessed on 22 October 2024).
80. Bagherian, B. How Dubai is becoming a Smart City. Baharash Architecture. 2017. Available online: <https://www.baharash.com/dubai-smart-city/> (accessed on 25 October 2024).
81. Landau, J. The Technology Behind Sidewalk Toronto's Concept Images. Urban Toronto. 2017. Available online: <https://urbantoronto.ca/news/2017/10/technology-behind-sidewalk-torontos-concept-images.29283> (accessed on 25 October 2024).
82. Arquitectura Viva Proyecto The Big U, Nueva York. 2019. Available online: <https://arquitecturaviva.com/obras/proyecto-the-big-u> (accessed on 25 October 2024).
83. City of Helsinki. Helsinki 3D. 2024. Available online: <https://www.hel.fi/en/decision-making/information-on-helsinki/maps-and-geospatial-data/helsinki-3d> (accessed on 27 September 2024).
84. Ziersen, J.; Clauson-Kaas, J.; Rasmussen, J. The role of Greater Copenhagen Utility in implementing the city's Cloudburst Management Plan. *Water Pract. Technol.* **2017**, *12*, 338–343. [CrossRef]
85. Urban Sustainability Exchange. Cloudburst Initiative Copenhagen. 2023. Available online: <https://use.metropolis.org/case-studies/cloudburst-initiative-copenhagen> (accessed on 20 September 2024).
86. Tokyo Metropolitan Government. Be Smart Tokyo. 2023. Available online: <https://www.be-smarttokyo.metro.tokyo.lg.jp/en/> (accessed on 27 September 2024).
87. Tokyo Metropolitan Government. Smart City Tokyo. 2024. Available online: <https://www.smart-tokyo.metro.tokyo.lg.jp> (accessed on 27 September 2024).
88. Nandkeolyar, K. Dubai's Smart City Plans Accelerated Due to Huge Cash Injection. 2023. Available online: <https://www.timeoutdubai.com/news/dubai-digital-strategy-2023-2030> (accessed on 27 September 2024).
89. Dubai Digital Authority. Digital Dubai. Available online: <https://www.digitaldubai.ae> (accessed on 27 September 2024).
90. Dubai Municipality. Geo Dubai. Available online: <https://geodubai.dm.gov.ae/ar/Pages/default.aspx> (accessed on 27 September 2024).
91. BBC News Mundo. Ciudad Inteligente de Google: 3 Interrogantes Sobre la Polémica urbe Proyectada Para 2022. 2019. Available online: <https://www.bbc.com/mundo/noticias-48460200> (accessed on 27 September 2024).
92. BBC News Mundo. Así será Quayside, el Polémico Barrio Futurista de Toronto Diseñado por Google. 2018. Available online: <https://www.bbc.com/mundo/noticias-44967032> (accessed on 27 September 2024).
93. Rebuild by Design. Project Pages: The Big U. 2022. Available online: <https://rebuildbydesign.org/work/funded-projects/the-big-u/> (accessed on 27 September 2024).
94. Archello. Big U. Available online: <https://archello.com/it/project/big-u> (accessed on 20 September 2024).
95. Hämäläinen, M. Urban development with dynamic digital twins in Helsinki city. *IET Smart Cities* **2021**, *3*, 201–210. [CrossRef]
96. Bentley Systems. City of Helsinki Expands Digitalization with Citywide Digital Twin. 2021. Available online: www.bentley.com (accessed on 27 September 2024).
97. City of Helsinki. Annual Report 2021. Helsinki. 2021. Available online: <https://www.hel.fi/static/kanslia/Julkaisut/2022/helsinki-annual-report-2021.pdf> (accessed on 27 September 2024).
98. City of Helsinki. Annual Report 2023. Helsinki. 2023. Available online: https://www.hel.fi/static/kanslia/Julkaisut/2024/Helsingin_kaupunki_vuosikertomus_2023_en.pdf (accessed on 27 September 2024).
99. City of Copenhagen. The City of Copenhagen. Cloudburst Management Plan 2012. 2012. Available online: <http://unix4.com/download.php?id=17212> (accessed on 27 September 2024).
100. Water Utility Climate Alliance. Case Study: City of Copenhagen Cloudburst Management Plan. Available online: www.wucaonline.org (accessed on 27 September 2024).
101. Holmbo Lind, M.; Eva Hansen, K.E. Adaptation Approaches in Danish Municipalities' Climate Action Plans. 2024. Available online: <https://www.realdania.org/publications/in-english/summary-adaptation-approaches-in-danish-municipalities-climate-action-plans> (accessed on 28 September 2024).

102. City of Copenhagen. CPH 2025 Climate Plan: Roadmap 2021–2025. Copenhagen. 2020. Available online: https://kk.sites.itera.dk/apps/kk_pub2/index.asp?mode=detalje&id=2062 (accessed on 28 September 2024).
103. Pham, C. Tokyo Smart City Development in Perspective of 2020 Olympics: Opportunities for EU-Japan Cooperation and Business Development. 2015. Available online: https://cdnw8.eu-japan.eu/sites/default/files/publications/docs/smart2020tokyo_final.pdf (accessed on 28 September 2024).
104. Lavigne, D.; Lavigne, H. DUBAI. Digital Twin. Available online: <https://storymaps.arcgis.com/stories/4ae54ecb2d8e4640b491de1fc319cffc> (accessed on 27 September 2024).
105. Moates, C. How the UAE Is Leading the Way in Digital Twin Integration. Available online: <https://landvault.io/blog/uae-leading-digital-twin-integration> (accessed on 27 September 2024).
106. Dubai Electricity & Water Authority. Dewa Pjsc Integrated Report 2023. 2023. Available online: https://static.mubasher.info/File_Mix_Announcement_File/A34881D1-7CB7-4A2D-8D12-7C98B555E6C4.pdf (accessed on 28 September 2024).
107. Toronto Zoo. Environmental Initiatives Report 2023. Toronto. 2024. Available online: <https://www.torontozoo.com/!/pdfs/green/2023-Environmental-Initiatives-Report-FINAL.pdf> (accessed on 28 September 2024).
108. City of Toronto. City of Toronto Environmental, Social & Governance (ESG): Performance Report. Toronto. 2024. Available online: <https://www.toronto.ca/legdocs/mmis/2024/ex/bgrd/backgroundfile-242216.pdf> (accessed on 28 September 2024).
109. U.S. Department of Housing and Urban Development. THE BIG “U”. Rebuild by Design: Promoting Resilience Post-Sandy Through Innovative Planning, Design & Programming. 2014. Available online: <https://rebuildbydesign.org/wp-content/uploads/2021/12/675.pdf> (accessed on 28 September 2024).
110. City of New York. Mayor Adams Announces First Section of East Side Coastal Resiliency Project Completed as Asser Levy Playground Reopens with new Floodwall and Resilient Play Areas. Website of the City of New York, 2022. Available online: <https://www.nyc.gov/office-of-the-mayor/news/518-22/mayor-adams-first-section-east-side-coastal-resiliency-project-completed-asser-levy#/0> (accessed on 17 October 2024).
111. Brinkhoff, T. City Population. City Population, 2024. Available online: <https://www.citypopulation.de/> (accessed on 7 November 2024).
112. Palomino, J. Co-Design and Citizen Participation Processes in the Climate Change Adaptation Projects of Copenhagen. 2017. Available online: <https://a21.dk/wp-content/uploads/2017/07/Jaime-Palomino-Co-Design-and-Citizen-ParticipationProcesses-in-the-Climate-ChangeAdaptation-Projects-of-Copenhagen.compressed.pdf> (accessed on 7 November 2024).
113. EIT Climate-KIC. Using Big Data and AI to Promote Citizen Participation. 2020. Available online: <https://pioneers.climate-kic.org/stories/using-big-data-and-ai-to-promote-citizen-participation/> (accessed on 28 September 2024).
114. Al Mar’ashi, H. Dubai Is a Smart City That Connects with People. Available online: <https://www.eeg-uae.org/dubai-is-a-smart-city-that-connects-with-people/> (accessed on 28 September 2024).
115. Participedia. Participatory Planning in the Sidewalk Toronto Project Copy Añadir a favoritos. Available online: <https://participedia.net/case/participatory-planning-in-the-sidewalk-toronto-project> (accessed on 27 September 2024).
116. NL Netherlands. First of coastal projects Lower Manhattan breaks ground. 2021. Available online: <https://www.dutchwatersector.com/news/first-of-coastal-projects-lower-manhattan-breaks-ground> (accessed on 27 September 2024).
117. Hilden, M.; Tikkakoski, P.; Sorvali, J.; Mettiäinen, I.; Käyhkö, J.; Helminen, M.; Määtä, H.; Berninger, K.; Meriläinen, P.; Ahonen, S.; et al. Adaptation to Climate Change in Finland: Current State and Future Prospects. 2022. Available online: https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/164414/VNTEAS_2022_61.pdf?sequence=1&isAllowed=y (accessed on 27 September 2024).
118. E.U. Danish Ministry of Climate. *Climate Programme 2020*; E.U. Danish Ministry of Climate: Budapest, Hungary, 2020; pp. 28–100.
119. City of Copenhagen. CPH 2025 Climate Plan: A Green, Smart and Carbon Neutral City. 2012. Available online: <https://c40.my.salesforce.com/sfc/p/#36000001Enhz/a/1Q000000MdWO/dqsA.6zzjWFvcNSPSzclx73AtkBaAedDk7mD7LYAjbw> (accessed on 10 October 2024).
120. Administración de Desastres en Japón. 2000. Available online: <http://www.ve.emb-japan.go.jp/esp/image/ADMINISTRACION-DE-DESASTRES-EN-JAPON.pdf> (accessed on 12 October 2024).
121. Agencia Meteorológica de Japón. Available online: <https://www.data.jma.go.jp/multi/index.html?lang=es> (accessed on 28 October 2024).
122. Ministry of Climate Change & Environment. National Climate Change Plan of the United Arab Emirates 2017–2050. 2017. Available online: www.moccae.gov.ae (accessed on 12 October 2024).
123. Dewan, A. Scientists Find the Fingerprints of Climate Change on Dubai’s Deadly Floods. 2024. Available online: <https://edition.cnn.com/2024/04/25/climate/dubai-floods-climate-weather-analysis-int/index.html> (accessed on 20 October 2024).
124. Toronto Water. 2023 Wet Weather Flow Master Plan Implementation Update. 2023. Available online: <https://www.toronto.ca/wp-content/uploads/2023/07/9033-2023-Wet-Weather-Flow-Master-Plan-Implementation-Update-with-Attachment-1.pdf> (accessed on 12 October 2024).
125. Balk, C.; Braneon, C.; Leichenko, R.; Moss, R.; Towers, J. Climate Risk and Equity: Advancing Knowledge Toward a Sustainable Future: Introduction. New York City Panel on Climate Change: NPCC 2024 Report. 2024. Available online: https://climateassessment.nyc/wp-content/uploads/2024/04/NPCC4_IntroductionInterimR2.pdf (accessed on 28 October 2024).
126. Howard, T.L.J.; Gaborit, N. Using Virtual Environment Technology to Improve Public Participation in Urban Planning Process. *J. Urban Plan. Dev.* **2007**, *133*, 233–241. [CrossRef]

127. Flood, S.; Cradock-Henry, N.A.; Blackett, P.; Edwards, P. Adaptive and interactive climate futures: Systematic review of ‘serious games’ for engagement and decision-making. *Environ. Res. Lett.* **2018**, *13*, 063005. [\[CrossRef\]](#)
128. Caragliu, A.; Del Bo, C.; Nijkamp, P. Smart Cities in Europe. *J. Urban Technol.* **2011**, *18*, 65–82. [\[CrossRef\]](#)
129. Mangnus, A.C.; Rebel, K.T.; Vervoort, J.M.; Dotinga, R.A.; Hoogendoorn, E.; Driessen, P.P.J.; Hajer, M.A. Picture the future, play the present: Re-imagining sustainable cities through a large-scale location-based game. *Futures* **2022**, *135*, 102858. [\[CrossRef\]](#)
130. Hamin Infield, E.M.; Abunnasr, Y.; Ryan, R.L. (Eds.) *Planning for Climate Change: A Reader in Green Infrastructure and Sustainable Design for Resilient Cities*, 1st ed.; Routledge: London, UK, 2018; ISBN 978-0815391685.
131. Alberti, M. *Advances in Urban Ecology: Integrating Humans and Ecological Processes in Urban Ecosystems*; Springer: New York, NY, USA, 2008; ISBN 978-0-387-92291-1.
132. Sassen, S. *Cities in a World Economy*, 5th ed.; SAGE Publications: Thousand Oaks, CA, USA, 2018; ISBN 978-1506362618.
133. Verba, S.; Lehman Schlozman, K.; Brady, H.E. *Voice and Equality: Civic Voluntarism in American Politics*; Harvard University Press: Cambridge, MA, USA, 1995; ISBN 978-0674942936.
134. Soederberg, S.; Walks, A. Producing and governing inequalities under planetary urbanization: From urban age to urban revolution? *Geoforum* **2018**, *89*, 107–113. [\[CrossRef\]](#)
135. Hajer, M.; Zonneveld, W. Spatial Planning in the Network Society-Rethinking the Principles of Planning in the Netherlands. *Eur. Plan. Stud.* **2000**, *8*, 337–355. [\[CrossRef\]](#)
136. Abdirahim Bashiir, A. Smart Cities and IoT for Sustainable Urban Development. *Res. Output J. Biol. Appl. Sci.* **2024**, *3*, 23–27.
137. Mehmood, R.; Yigitcanlar, T.; Corchado, J.M. Smart Technologies for Sustainable Urban and Regional Development. *Sustainability* **2024**, *16*, 1171. [\[CrossRef\]](#)
138. Hollands, R.G. Will the real smart city please stand up? Intelligent, progressive or entrepreneurial? In *The Routledge Companion to Smart Cities*; Routledge: London, UK, 2020; p. 21. ISBN 9781315178387.
139. Follador, D.; Tremblay-Racicot, F.; Duarte, F.; Carrier, M. Collaborative Governance in Urban Planning: Patterns of Interaction in Curitiba and Montreal. *J. Urban Plan. Dev.* **2021**, *147*, 04020056. [\[CrossRef\]](#)
140. Carr, C.; Hesse, M. Technocratic Urban Development: Large Digital Corporations as Power Brokers of the Digital Age. *Plan. Theory Pract.* **2022**, *23*, 476–485. [\[CrossRef\]](#)
141. Akasha, H.; Ghaffarpasand, O.; Pope, F.D. Climate Change, Air Pollution and the Associated Burden of Disease in the Arabian Peninsula and Neighbouring Regions: A Critical Review of the Literature. *Sustainability* **2023**, *15*, 3766. [\[CrossRef\]](#)
142. International Federation of Red Cross and Red Crescent Societies (IFRC). United Arab Emirates (UAE) Climate Fact Sheet. 2018. Available online: <https://gco.iarc.fr/today/data/factsheets/populations/784-united-arab-emirates-fact-sheets.pdf> (accessed on 12 October 2024).
143. World Bank. “Country United Arab Emirates”, Climate Change Knowledge Portal. 2021. Available online: <https://climateknowledgeportal.worldbank.org/country/united-arab-emirates> (accessed on 28 October 2024).
144. Hijioka, Y. Climate Change Adaptation Information Platform (A-PLAT). 2020. Available online: <https://weadapt.org/knowledge-base/climate-change-adaptation-knowledge-platforms/climate-change-adaptation-information-platform-a-plat/> (accessed on 18 October 2024).
145. Japan Meteorological Agency. Annual Report on Global Extreme Climate Events. 2024. Available online: <https://www.data.jma.go.jp/tcc/tcc/products/climate/annual/index.html> (accessed on 20 October 2024).
146. Geels, F.W. Socio-technical transitions to sustainability: A review of criticisms and elaborations of the Multi-Level Perspective. *Curr. Opin. Environ. Sustain.* **2019**, *39*, 187–201. [\[CrossRef\]](#)
147. Chourabi, H.; Nam, T.; Walker, S.; Gil-Garcia, J.R.; Mellouli, S.; Nahon, K.; Pardo, T.A.; Scholl, H.J. Understanding Smart Cities: An Integrative Framework. In Proceedings of the 45th Hawaii International Conference on System Sciences, Maui, HI, USA, 4–7 January 2012; pp. 2289–2297.
148. van Zoonen, L. Privacy concerns in smart cities. *Gov. Inf. Q.* **2016**, *33*, 472–480. [\[CrossRef\]](#)
149. Elmaghraby, A.S.; Losavio, M.M. Cyber security challenges in smart cities: Safety, security and privacy. *J. Adv. Res.* **2014**, *5*, 491–497. [\[CrossRef\]](#)
150. Kitchin, R. The ethics of smart cities and urban science. *Philos. Trans. R. Soc. A Math. Phys. Eng. Sci.* **2016**, *374*, 20160115. [\[CrossRef\]](#)
151. Evans, J.; Karvonen, A.; Raven, R. (Eds.) *The Experimental City*, 1st ed.; Routledge: London, UK, 2018; ISBN 9781138299672.
152. Bulkeley, H. *Cities and Climate Change*, 1st ed.; Routledge: London, UK, 2013; ISBN 9780415597050.

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