

Article

# Connecting the green to the digital: Integrating Eco Cities and Smart Regions

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## CITATION

Bauermann BFC, Bussador A, Bauermann HB, Matrakas MD. Connecting the green to the digital: Integrating eco cities and smart regions. *Eco Cities*. 2024; 5(1): 2755. <https://doi.org/10.54517/ec.v5i1.2755>

## ARTICLE INFO

Received: 31 May 2024

Accepted: 26 June 2024

Available online: 14 August 2024

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**Abstract:** This article explores the integration of Eco Cities and Smart Regions to create sustainable and innovative urban environments. Eco Cities focus on environmental sustainability through renewable energy, waste management, and green infrastructure, aiming to reduce ecological footprints and promote healthy lifestyles. Smart Regions, on the other hand, utilize advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), and big data analytics to enhance public service efficiency, optimize resource use, and foster economic development. The study highlights how combining these two approaches can lead to significant benefits, including improved operational efficiency, better quality of life, environmental resilience, and active citizen participation. Case studies of cities like Copenhagen and Singapore demonstrate successful integration, showcasing achievements in sustainability and technological innovation. The article also identifies the main challenges in this integration, including technical compatibility, cybersecurity risks, high initial investments, digital inequality, and the need for robust governance frameworks. Overcoming these challenges requires collaborative efforts among governments, private sectors, and civil society, as well as innovative financing strategies and capacity-building programs. Future considerations emphasize the need for a holistic approach to urban planning that incorporates emerging technologies, flexible and adaptive strategies, and inclusive citizen engagement. By addressing these factors, cities and regions can become more resilient, sustainable, and inclusive, meeting the needs of both current and future generations. This integrated approach promises to transform urban environments into hubs of sustainability and innovation, driving long-term positive outcomes for society and the environment.

**Keywords:** sustainable urban environments; Eco Cities; Smart Regions; renewable energy; advanced technologies; citizen participation; environmental resilience; urban planning integration

## 1. Introduction

Smart Regions are geographical areas, such as cities, metropolitan regions, or rural areas, that adopt advanced information and communication technology strategies to improve the quality of life for residents, drive sustainable economic growth, and increase the efficiency of public service delivery [1]. These regions utilize a variety of smart technologies, such as the Internet of Things, data analytics, artificial intelligence, and geographic information systems, to optimize resource use, promote innovation, improve governance, and engage citizens in decision-making [2]. The goal of Smart Regions is to create more connected, accessible, inclusive, and sustainable urban and regional environments that can address the complex challenges of the 21st century, such as climate change, rapid urbanization, and social

inequalities [1–3].

Eco Cities, on the other hand, are urban environments that are planned and designed with a strong focus on environmental sustainability, aiming to reduce negative environmental impacts and promote more sustainable lifestyles for their inhabitants [4]. These cities adopt a range of eco-friendly practices, such as energy efficiency, use of renewable energy, waste management, preservation of green areas, and promotion of sustainable mobility [4]. The urban planning of Eco Cities incorporates principles of sustainable urban design, such as appropriate housing density, efficient public transportation, accessible green spaces, and green infrastructure. The goal of Eco Cities is to create healthier, more resilient, and environmentally conscious urban environments that can offer a high quality of life for residents while protecting and conserving natural resources for future generations [4].

The importance of sustainability and technology in modern urban management is crucial for addressing the increasingly complex challenges faced by cities in the 21st century [5]. The key points that stand out in this importance are associated with sustainability in urban management, involving the preservation of natural resources, resilience to climate change and quality of life for residents; and technology in urban management, involving efficiency in public service delivery, monitoring and data analysis, engagement and democratic participation, innovation and economic development, and integration of sustainability and technology [1,3,5].

Cities consume a significant number of natural resources, such as water, energy, and materials, and produce large quantities of waste. Sustainable urban management aims to preserve these resources and reduce waste, ensuring their availability for future generations [5]. Furthermore, cities are vulnerable to extreme weather events such as floods, droughts, and storms, which are becoming more frequent and intense due to climate change. Sustainable urban management involves adapting to and mitigating these impacts, making cities more resilient and capable of facing climate challenges [4–6]. A sustainable city promotes a high quality of life for its residents by providing access to green spaces, clean air, safe drinking water, efficient transportation, and adequate housing, thereby improving not only the well-being of residents but also attracting investments and talent to the city [4,6].

When it comes to technology in urban management, it's noteworthy that technology can be used to optimize the delivery of public services such as waste collection, water supply, public transportation, and security. Smart systems can improve operational efficiency, reduce costs, and enhance service quality for citizens. Technology enables real-time monitoring and analysis of large volumes of data on various aspects of the city, including traffic, air pollution, energy consumption, and land use patterns. This provides valuable insights for urban managers, enabling more informed and evidence-based decision-making [5].

Digital platforms and mobile applications can be used to engage citizens in city management, allowing them to express their opinions, report issues, and actively participate in the decision-making process. This promotes greater transparency, accountability, and democratic participation in urban governance. Furthermore, the adoption of innovative technologies in urban management can stimulate economic development, attract investments, and promote job creation in the technology sector.

Cities that are seen as leaders in innovation tend to be more attractive to businesses and entrepreneurs, driving sustainable economic growth [5,6].

Given this, the effective integration of sustainable practices with advanced technologies is essential for successful urban management in the modern world. This enables cities to address environmental, social, and economic challenges in a holistic manner, creating more resilient, inclusive, and sustainable urban environments for all their inhabitants [5,6].

In this context, the aim of this article is to explore and analyze the relationship between Smart Regions and Eco Cities, examining how these two complementary concepts can be integrated and interact to promote more sustainable, efficient, and innovative urban and regional environments. Specifically, the article seeks to:

- Provide a clear understanding of the concepts of Smart Regions and Eco Cities, highlighting their characteristics, objectives, and key strategies.
- Analyze how practices and technologies adopted in Smart Regions can be applied in Eco Cities, and vice versa, identifying areas of intersection and opportunities for synergy.
- Present concrete examples of cities, regions, or projects that exemplify successful integration between Smart Regions and Eco Cities, highlighting the practices and technologies used and the results achieved.
- Evaluate the potential benefits of integration between Smart Regions and Eco Cities, including operational efficiency, quality of life for inhabitants, environmental resilience, and innovation.
- Discuss the challenges and obstacles faced in implementing this integration.

In summary, the effective integration of Smart Regions and Eco Cities represents a comprehensive and progressive approach to sustainable urban management in the modern world. By combining sustainable practices with advanced technologies, cities can address environmental, social, and economic challenges more effectively, creating more resilient, inclusive, and sustainable urban and regional environments for all their inhabitants [6–8]. This integration not only enhances quality of life and operational efficiency but also drives innovation, attracts investments, and promotes sustainable economic growth. However, it is important to recognize and overcome the challenges and obstacles associated with implementing this integration, working collaboratively with all stakeholders involved. With continued efforts and commitment, we can build cities of the future that are truly smart, eco-friendly, and prosperous [7].

## **2. Methodology**

To conduct this research on the integration of Eco Cities and Smart Regions, a qualitative and exploratory approach was adopted, aiming to understand and analyze the intersections and complementarities between sustainable practices and advanced technologies in the urban context. The methodology followed these steps:

- Literature review: a comprehensive review of existing literature on Eco Cities and Smart Regions was conducted, focusing on academic articles, reports from international organizations, and relevant case studies. The literature review

helped identify the main characteristics, objectives, and strategies associated with both concepts.

- Case studies: some cities and regions exemplifying successful integration between ecological practices and smart technologies were selected. Examples include Copenhagen and Singapore. These case studies were analyzed to highlight the adopted practices, achieved results, and challenges faced.
- Comparative analysis: a comparative analysis was conducted to identify areas of intersection and synergy between Eco City and Smart Region practices. Themes such as resource management, urban mobility, citizen participation, and environmental resilience were examined.
- Discussion of challenges and opportunities: the research also addressed the main technical, financial, and social challenges in implementing the integration between Eco Cities and Smart Regions. Potential solutions and innovative strategies were discussed based on the collected data and the reviewed literature.
- Formulation of recommendations: based on the analyses and research findings, recommendations were formulated for urban managers, policymakers, and other stakeholders on how to effectively promote the integration of sustainable practices and advanced technologies to create resilient, sustainable, and innovative urban environments.

This methodology allowed for a deep and multifaceted understanding of the subject, enabling the formulation of practical insights and recommendations for the integration of Eco Cities and Smart Regions.

### **3. Characteristics of Eco Cities and Smart Regions**

Eco Cities are urban environments planned and designed with the primary goal of minimizing environmental impact and promoting sustainability in all dimensions [4,6,8]. These cities are built on principles and practices aimed at balancing urban growth with the conservation of natural resources, protection of the environment, and improvement of the quality of life of their inhabitants. The main characteristics of Eco Cities are [8]:

- Incorporation of technologies and practices to reduce energy consumption and promote the use of renewable sources such as solar, wind, and biomass energy;
- Implementation of efficient systems for collection, recycling, and treatment of solid and liquid waste, aiming to reduce waste and minimize pollution;
- Promotion of efficient public transportation, encouragement of biking and walking, urban planning that prioritizes pedestrians, and reduction of private vehicle usage;
- Urban planning that prioritizes the creation and maintenance of parks, gardens, and green areas, contributing to biodiversity and air quality; and
- Use of eco-friendly construction materials, architectural design focused on natural light utilization, and efficient climate control systems.

Among the most successful Eco Cities in the world are [9]: (i) Copenhagen, Denmark: The Danish capital is known for its ambitious sustainability initiatives, including goals to become carbon-neutral by 2025, investments in cyclist infrastructure, and energy efficiency programs; (ii) Vancouver, Canada: Vancouver

is internationally recognized as a leading Eco City, with policies and programs focused on green space protection, water conservation, public transportation promotion, and sustainable building construction; (iii) Freiburg, Germany: Freiburg is a reference in Eco Cities in Germany, with a holistic approach to sustainability, including investments in solar energy, efficient public transportation, and eco-friendly buildings; and (iv) Curitiba, Brazil: Curitiba is a notable example of an Eco City in Latin America, with its integrated public transportation system, extensive green areas, and innovative waste management policies.

These examples highlight the success of different approaches to creating Eco Cities around the world, demonstrating how these cities can be modeled to promote a sustainable and resilient lifestyle in harmony with the environment [9].

Smart Regions, on the other hand, refer to geographical areas that use technology and innovation to improve the quality of life of their inhabitants, drive economic development, and promote sustainability [1]. The main characteristics of Smart Regions are [1,2,7,10]:

- Investment in information and communication technology (ICT) infrastructure, including fiber-optic networks, high-speed connectivity, and data infrastructure to support a wide range of digital services;
- Real-time collection and analysis of data from various sources, such as sensors, mobile devices, and social networks, to gain insights into the functioning of the region and support evidence-based decision-making;
- Adoption of participatory governance models, involving citizens, businesses, and civil society organizations in planning and decision-making on urban and regional issues;
- Encouragement of innovation and entrepreneurship, creating favorable ecosystems for the development of startups, industrial clusters, and technology parks;
- Promotion of sustainable economic growth, creating quality jobs, stimulating high-value-added sectors, and promoting social inclusion.

Among the most successful Smart Regions in the world are: (i) Silicon Valley, California, USA: Recognized as the global epicenter of technological innovation, Silicon Valley is a paradigmatic example of a Smart Region, with a concentration of technology companies, leading universities, and a vibrant entrepreneurial ecosystem [11]; (ii) Eindhoven, Netherlands: Known as the "Design Capital," Eindhoven has become a leading Smart Region in Europe, with investments in research and development, collaboration between companies and universities, and a strong culture of innovation [12]; (iii) Songdo, South Korea: Built from scratch as a smart city, Songdo is an example of a Smart Region that integrates advanced technologies to improve quality of life, sustainability, and operational efficiency [13]; and (iv) Barcelona, Spain: Barcelona is a reference in Smart Regions in Europe, with innovative projects in areas such as urban mobility, waste management, renewable energy, and digital governance [14].

These examples demonstrate how Smart Regions can evolve into hubs of innovation and prosperity, using technology as a catalyst for regional economic and social development.

### 3.1. Intersections and complementarities in environmental sustainability

Both Eco Cities and Smart Regions share the common goal of promoting environmental sustainability, although their approaches and emphases may vary. While Eco Cities adopt a holistic approach to minimizing the environmental impact of urban activities, integrating practices and policies that promote conservation of natural resources, protection of biodiversity, and reduction of carbon emissions, Smart Regions incorporate advanced technologies and intelligent systems to optimize the use of natural resources, reduce waste, and promote energy efficiency [4,8,9] (Table 1).

**Table 1.** Ecological practices in Eco Cities vs. Sustainable technologies in Smart Regions [1,2,7,9].

Eco Cities (Ecological Practices) [9]	Smart Regions (Sustainable Technologies) [1,2,7]
Utilization of renewable energy sources such as solar and wind power to reduce dependence on fossil fuels.	Implementation of smart energy grids that monitor and control electricity flow efficiently, reducing losses, and promoting the use of renewable energy.
Encouragement of the use of public transportation, bicycles, and walking to reduce greenhouse gas emissions and improve air quality.	Use of sensors and monitoring systems to manage water consumption, detect leaks, and optimize the use of water resources.
Implementation of recycling and composting programs to reduce the volume of waste sent to landfills and minimize soil and water pollution.	Implementation of intelligent transportation systems that optimize traffic flow, reduce congestion and greenhouse gas emissions, and promote alternative forms of mobility such as car-sharing and public transportation.
Preservation and expansion of green areas, urban parks, and ecological corridors to promote biodiversity and mitigate the effects of urban heat islands.	

For each thematic area covering sustainability and technology in public management, examples of integration between the practices of an Eco City and a Smart Region can be cited, combining traditional ecological practices with advanced technologies to promote environmental sustainability in urban and regional environments.

As for the use of renewable energies, an Eco City can implement solar panels on residential and commercial buildings to generate clean electricity locally, while a Smart Region can integrate this solar energy into a smart grid, allowing for efficient storage and distribution of electricity throughout the region [4,6,8].

In the case of efficient waste management, an Eco City can adopt selective collection systems and composting to reduce the amount of waste sent to landfills, while a Smart Region can use IoT technologies to monitor waste levels in garbage containers, optimizing collection routes, and reducing operational costs [4,8].

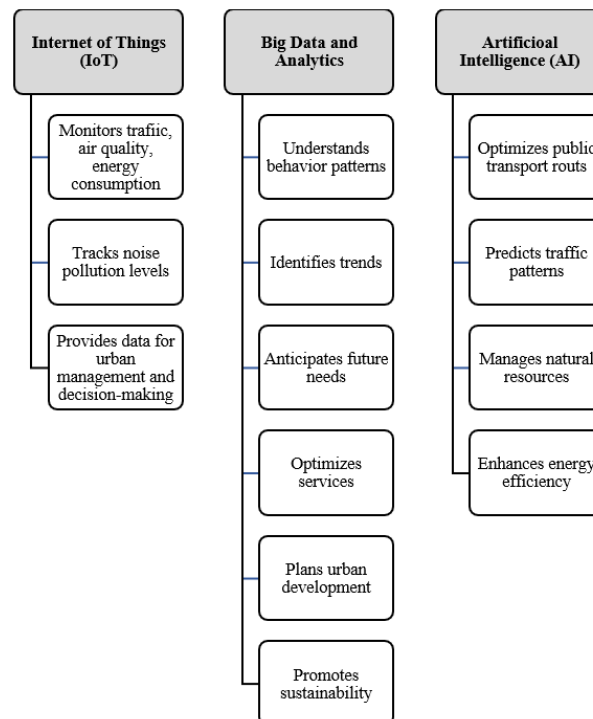
Regarding sustainable transportation, an Eco City can invest in infrastructure for bike lanes and electric public transportation, while a Smart Region can implement intelligent transportation systems that integrate real-time traffic data, providing more efficient routes and reducing congestion and pollutant emissions [4,8].

### 3.2. Intersections and complementarities in technology usage

When it comes to the role of technology, there is no doubt that it should be used for the benefit of society. In Eco Cities, technology is used to monitor air, water, and soil quality. IoT sensors are deployed throughout the city to collect real-time data and identify potential environmental issues. Technologies such as IoT are also employed in efficient waste management, allowing for monitoring of waste volume in containers, optimizing collection routes, and encouraging recycling. Additionally, Eco Cities invest in technologies to promote energy efficiency, including intelligent LED lighting systems, energy consumption monitoring in buildings, and renewable energy networks [8,9].

Technology also plays a fundamental role in optimizing processes and improving operational efficiency in Smart Regions. Intelligent monitoring and control systems enable efficient management of resources such as energy, water, and transportation. Real-time data collection and analysis provide valuable insights for decision-makers. The use of big data and analytics allows for a deeper understanding of urban patterns and citizen needs, supporting more effective public policies. Technology is also employed to enhance the quality of life for inhabitants of Smart Regions, including everything from intelligent transportation systems to digital health solutions and citizen engagement platforms [2,8,9,15].

Some technologies have broad applications in both concepts, Eco Cities and Smart Regions, such as those in **Figure 1**.



**Figure 1.** Technologies applications in Eco Cities and Smart Regions [10,15,16].

These examples highlight how technology can be a key element in promoting sustainability in both Smart Regions and Eco Cities, enabling more efficient management, more informed decision-making, and an overall improvement in the quality of life for inhabitants.

### **3.3. Intersections and complementarities in mobility and transportation**

Regarding sustainable transportation strategies in Eco Cities, it is important to highlight that they encourage the use of public transportation as a sustainable alternative to individual transport. This includes the expansion of bus, metro, tram, and high-speed train networks. Eco Cities also invest in safe and efficient cycling infrastructure, such as segregated bike lanes, bike parking facilities, and bike-sharing systems. Additionally, they promote urban planning that encourages walking and short commutes, and the implementation of policies to discourage the use of combustion vehicles, such as urban tolls, low-emission zones, and tax incentives for electric vehicles [4,8,9,17].

On the other hand, smart mobility solutions in Smart Regions involve Intelligent Transportation Systems (ITS). Smart Regions implement intelligent transportation systems that use technologies such as sensors, GPS, vehicle communication, and adaptive traffic signals to improve traffic flow, reduce congestion, and minimize travel time. Additionally, mobile applications are developed to provide real-time information on transportation options, such as bus schedules, bike routes, car sharing, and parking availability [1,2]. Complementarily, Smart Regions promote the integration of autonomous and connected vehicles into the transportation infrastructure, enabling more efficient, safe, and coordinated driving, as well as reducing the space needed for parking [1,2].

When analyzing the combined impact of Eco Cities and Smart Regions, the following points can be highlighted:

- By prioritizing public transportation, bicycles, and walking, Eco Cities significantly reduce greenhouse gas emissions and air pollutants associated with the use of motor vehicles. Additionally, smart mobility solutions in Smart Regions optimize traffic flow, reducing congestion and the time vehicles spend on the streets, contributing to further emission reductions.
- The promotion of sustainable forms of transportation not only reduces air and noise pollution but also creates healthier and more pleasant urban environments for residents. Moreover, smart mobility solutions in Smart Regions make commutes more efficient and convenient, reducing traffic-related stress and improving access to services and opportunities.
- By encouraging the use of bicycles and walking as modes of transportation, Eco Cities promote a more active and healthier lifestyle among residents, contributing to the reduction of sedentary-related diseases and the overall well-being of the population.

The convergence of these practices and technologies results in more sustainable, resilient, and livable cities, providing a better quality of life for their inhabitants and contributing to the mitigation of environmental impacts.

### **3.4. Intersections and complementarities in resource management**

Regarding resource management approaches in Eco Cities, it is noted that they implement water conservation practices such as rainwater harvesting, greywater recycling, and the adoption of low-consumption technologies like efficient faucets and showers. Additionally, monitoring systems are used to identify leaks and



optimize water usage in buildings and public spaces [8,9].

Eco Cities also prioritize the use of renewable energy and energy efficiency in buildings, infrastructure, and transportation, which includes the installation of solar panels, wind turbines, cogeneration systems, and LED lighting. Additionally, monitoring technologies are employed to track energy consumption and identify opportunities for savings [4,8,9].

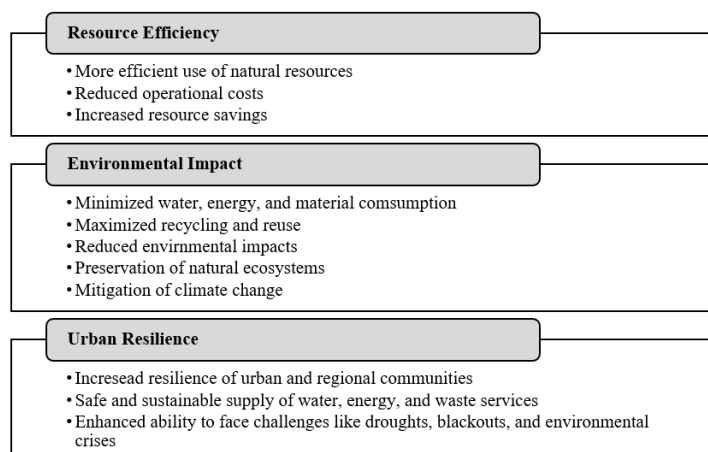
Additionally, Eco Cities adopt strategies for waste reduction, reuse, and recycling to minimize the volume of waste sent to landfills. This includes programs for selective collection, organic waste composting, and incentives for conscious production and consumption. Monitoring technologies are used to track waste flow and optimize collection routes [8,9,17].

On the other hand, resource management approaches in Smart Regions involve the implementation of intelligent water management systems that monitor consumption, detect leaks, and optimize water distribution. Technologies such as IoT sensors, smart meters, and automated distribution networks ensure efficient and sustainable use of water resources.

Smart Regions also integrate smart energy grids that allow for efficient monitoring and control of energy production, distribution, and consumption. This includes the use of smart meters, energy storage systems, and active demand management to optimize electricity supply, reduce costs, and reduce emissions [3,10].

Additionally, Smart Regions employ advanced technologies to optimize waste collection, sorting, recycling, and disposal. This includes intelligent collection systems with fill-level sensors, dynamic collection routes, and automated recycling facilities. Furthermore, tracking and monitoring solutions are used to ensure compliance with environmental regulations and reduce waste [3,7].

The benefits of integrating conservation practices with monitoring and optimization technologies in Eco Cities and Smart Regions include (**Figure 2**).



**Figure 2.** Benefits of integrating conservation practices in Eco Cities and Smart Regions.

The application of these practices not only promotes environmental sustainability but also ensures that cities and regions are prepared to face future

challenges while maintaining the quality of life for their inhabitants. In this way, the convergence of conservation practices and advanced technologies establishes a robust model for sustainable and resilient urban development.

### 3.5. Intersections and complementarities in quality of life and citizen participation

Eco Cities prioritize urban planning that enhances residents’ well-being, including access to green spaces, recreational areas, and healthcare infrastructure. This involves creating parks, squares, and green corridors that encourage social interaction, physical activity, and contact with nature [4,9]. Eco Cities also invest in green infrastructure, such as green roofs, living walls, and permeable areas, which help reduce the impact of urban heat islands, improve air quality, and enhance resilience to climate change [4,8,17–19].

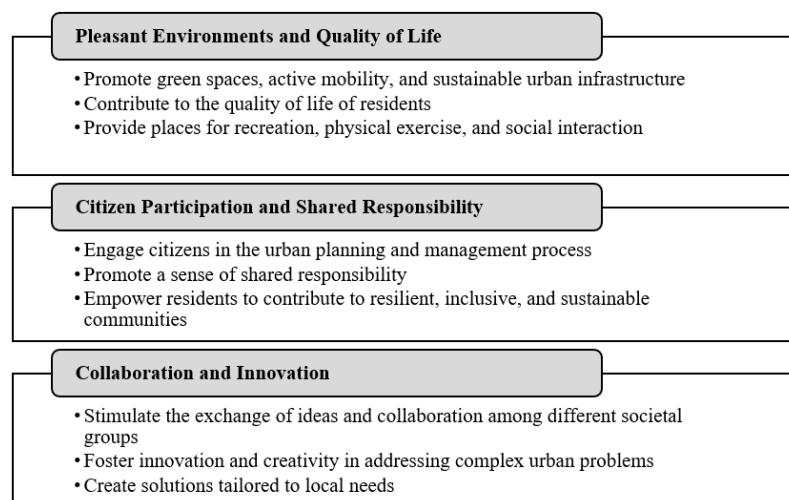
Additionally, Eco Cities promote the use of active transportation modes, such as walking and cycling, by creating safe and pleasant infrastructure, including wide sidewalks, segregated bike lanes, and scenic routes [8,9].

On the other hand, citizen engagement through digital platforms and open data in Smart Regions stems from the fact that they develop digital platforms that enable citizens to actively participate in urban planning, providing feedback, suggesting ideas, and participating in public consultations on urban and regional issues [10].

Smart Regions provide open data on different aspects of the city, such as air quality, traffic conditions, public spending, and urban development projects. This allows citizens to access information and better understand how the city operates [10].

Smart Regions encourage citizen engagement in local initiatives, such as volunteer programs, public interest groups, and urban environment improvement projects. This active participation strengthens the sense of community and promotes a feeling of belonging [10].

The synergies between creating pleasant environments and active citizen participation in Eco Cities and Smart Cities involve (**Figure 3**):



**Figure 3.** Benefits of integrating conservation practices in Eco Cities and Smart Regions.

The integration of pleasant environments with active citizen participation not only enhances the livability of Eco Cities and Smart Cities but also ensures their sustainable and resilient development. This holistic approach creates urban spaces that are not only efficient and functional but also vibrant and inclusive, ultimately contributing to a higher quality of life for all residents.

#### **4. Discussion of benefits and challenges of integration between Eco Cities and Smart Regions**

The integration of ecological practices and smart technologies can significantly enhance the efficiency and sustainability of cities and regions. Technologies like IoT, big data, and artificial intelligence enable more efficient management of resources such as energy, water, and waste, resulting in reduced waste and more rational use of natural resources [9,15]. Integrating intelligent systems for transportation, energy, and urban management allows for optimization of urban infrastructure, reducing congestion, improving energy efficiency in buildings, and ensuring more efficient use of urban space. By promoting the use of renewable energies, public transportation, and energy-efficient practices, the integration of ecological practices and smart technologies contributes to reducing greenhouse gas emissions and other pollutants, helping to combat climate change and improve air quality [9].

The integration of Eco Cities and Smart Regions also brings a host of tangible benefits to residents' quality of life. Promoting green spaces, reducing pollution, and improving air quality result in healthier and more pleasant urban environments to live in, reducing the risks of environmentally related diseases. Smart technologies in transportation, healthcare, and education increase residents' access to a wide range of services and opportunities, promoting social and economic inclusion. Active citizen participation in the urban planning and management process strengthens the sense of community and belonging, creating stronger and more resilient social bonds [9].

Furthermore, the integration of ecological practices and smart technologies enhances the resilience of cities and regions to future challenges. Implementing green infrastructure, smart drainage systems, and climate contingency plans helps cities adapt to climate change and minimize the impacts of extreme events, such as floods and heatwaves. The use of monitoring and communication technologies enables a more effective response to crises and natural disasters, facilitating the evacuation of at-risk areas, coordinating relief efforts, and minimizing damage [9,10].

The integration of practices and technologies that promote efficiency, sustainability, and social inclusion makes cities better prepared to tackle the challenges of population growth, rapid urbanization, and environmental pressures, ensuring a more resilient and sustainable urban development in the long term [10].

##### **4.1. Successful cities in integrating aspects of Eco Cities and Smart Regions**

Copenhagen and Singapore have been successful in integrating aspects of Eco Cities and Smart Regions, achieving positive outcomes in terms of sustainability, innovation, and quality of life for their residents. The lessons learned from these

examples can serve as inspiration for other cities around the world seeking to follow a similar path [20].

Copenhagen is recognized as an exemplary city that integrates aspects of both Eco Cities and Smart Regions. The city has adopted a holistic approach to promoting sustainability and innovation in all areas of urban development. Copenhagen has invested in high-quality cycling infrastructure, with over 400 km of segregated bike lanes, bike parking facilities, and adaptive traffic signals. Additionally, the city has an efficient public transportation system, with electric buses and trains powered by renewable energy [20,21].

The city has implemented a system of selective waste collection and recycling, achieving high recycling rates. Moreover, it has adopted monitoring technologies to optimize collection routes and reduce waste [20].

Copenhagen has prioritized the creation of green spaces and recreational areas, including urban parks, squares, and community gardens. The city has also invested in green roofs and living walls to improve air quality and reduce the impact of heat islands [20,21].

Singapore is another notable example of successful integration of Eco Cities and Smart Regions. The city-state has adopted an innovative approach to promoting sustainability and quality of life for its residents, combining environmental practices with cutting-edge technologies [22,23].

Singapore has implemented a smart energy grid and invested in LED lighting systems and solar energy. As a result, the city has significantly reduced energy consumption and carbon emissions [22,23].

The city has adopted advanced technologies to monitor and optimize water usage, including smart metering systems and water reuse for non-potable purposes. This has helped Singapore ensure a safe and sustainable water supply despite its water scarcity [23].

Singapore also actively involves its citizens in the urban planning process and decision-making through digital platforms and public consultations. This inclusive approach has promoted a greater sense of belonging and responsibility in the community [22].

## 4.2. Challenges

The integration of Eco Cities and Smart Regions approaches faces a series of technical, financial, and social challenges that may hinder their effective implementation [24,25] (**Table 2**).

**Table 2.** Challenges in integrating Eco Cities and Smart Regions [4,8–10,18,19,24,25].

Challenges	Explanation
Technical	Compatibility of technologies
	The integration of different systems and technologies can be complex due to the lack of standardization and interoperability between existing systems.
	Cybersecurity
	The increase in connectivity and digitalization can raise the risks of cyberattacks, requiring robust security measures to protect critical data and systems.

**Table 2.** (Continued).

Challenges		Explanation
Financial	High initial investments	The implementation of green infrastructure, smart systems, and monitoring technologies requires significant investments that are not always available, especially for cities and regions with limited resources.
	Financing models	The lack of adequate financing models can hinder the acquisition of necessary resources for long-term projects, especially those related to sustainability and innovation.
Social	Digital inequality	The adoption of smart technologies can widen the digital divide among citizens, leaving those with less access to technology or digital skills behind.
	Limited citizen participation	The lack of active engagement and participation of citizens in the planning and implementation process can lead to a lack of acceptance and resistance to proposed changes.
Governance	Interinstitutional coordination	The integration of approaches from Eco Cities and Smart Regions often requires coordination and collaboration between multiple actors and government agencies, which can be difficult to achieve due to organizational and conflicting interests.
	Outdated policies and regulations	Obsolete policies and regulations can represent barriers to adopting innovative practices and technologies, hindering the implementation of sustainable and smart solutions.

Overcoming these challenges requires a joint and collaborative effort between governments, the private sector, civil society, and academia, as well as a commitment to innovation, sustainability, and social inclusion [4]. Innovative financing strategies, incentive policies, and capacity-building programs can help mitigate these challenges and accelerate the transition to more sustainable and smart cities and regions [8].

## 5. Conclusion

The future of sustainable and smart cities and regions will likely involve a deeper integration between the approaches of Eco Cities and Smart Regions, aiming to create holistic urban environments that promote sustainability, innovation, and quality of life. Future research and practices should adopt an ecosystemic approach, considering the interconnection and interdependence of different urban systems such as transportation, energy, water, waste, and green spaces.

The development and adoption of emerging technologies such as artificial intelligence, the Internet of Things, blockchain, and augmented reality offer unprecedented opportunities to transform the way cities and regions are planned, built, and managed. In addition to technological advancements, it is necessary to explore new business models and public-private partnerships that encourage investments in sustainable and smart solutions and promote urban innovation.

The cities and regions of the future must focus on increasing their resilience and adaptive capacity to face emerging challenges such as climate change, population growth, urban migration, and pandemics. Flexible and adaptive urban planning strategies, along with investments in green infrastructure and smart technologies, can help cities and regions adapt to the rapid and unpredictable changes in the urban environment.

Active and inclusive citizen participation must be a priority in the design and implementation of urban projects, ensuring that the needs and concerns of all societal groups are considered. The cities and regions of the future must strive to promote equity and social justice, ensuring that the benefits of sustainability and innovation are distributed fairly and equitably among all their inhabitants.

Exploring these future considerations and areas of research and innovation is essential for creating more resilient, sustainable, smart, and inclusive cities and regions that meet the needs and aspirations of present and future generations.

Collaboration between urban planners, technologists, and communities is fundamental for the development of sustainable and smart urban environments. Only by integrating multidisciplinary knowledge and perspectives can the complex challenges faced by 21st century cities be addressed. It is important to recognize the central role of citizens as agents of change and active participants in the urban planning and management process. Community involvement is essential to ensure that proposed solutions meet the needs and aspirations of local residents.

For governments, businesses, and citizens interested in promoting Eco Cities and Smart Regions, it is essential to take concrete steps to transform visions into reality, such as: funding research and pilot projects that explore new solutions and technologies to make cities more sustainable and smart; creating policies and incentive programs that encourage sustainable practices and urban innovation; promoting public-private partnerships for investments in green infrastructure and smart technologies; and educating and raising awareness among the population about the importance of urban sustainability and responsible resource use, encouraging the adoption of more sustainable behaviors and lifestyles.

Through these collaborative and committed actions, everyone can work together to create cities and regions that are not only more sustainable and smarter but also more inclusive and resilient for all their inhabitants.

**Author contributions:** Conceptualization, BFCB; formal analysis, BFCB, AB, HBB and MDM; investigation, BFCB and AB; resources, BFCB; data curation, BFCB and AB; writing—original draft preparation, BFCB and HBB; writing—review and editing, BFCB, AB and HBB; visualization, HBB and MDM; supervision, BFCB and AB; project administration, BFCB. All authors have read and agreed to the published version of the manuscript.

**Conflict of interest:** The authors declare no conflict of interest.

## References

1. Bauer M, Helbig D, Mokhov V, et al. Smart Region concept as a solution for sustainable development for region with a rural and urban character. *Journal of Physics: Conference Series*. 2019; 1415: 012018. doi: 10.1088/1742-6596/1415/1/012018
2. Billones RKC, Guillermo MA, Lucas KC, et al. Smart Region Mobility Framework. *Sustainability*. 2021; 13(11): 6366. doi: 10.3390/su13116366
3. Gupta AK, Chinchwade P, Gupta H, et al. Sustainable and Smart Regions. *Human-Machine Interaction and IoT Applications for a Smarter World*. Published online June 13, 2022: 255-269. doi: 10.1201/9781003268796-20
4. Mersal A. Eco City Challenge and Opportunities in Transferring a City in to Green City. *Procedia Environmental Sciences*. 2017; 37: 22-33. doi: 10.1016/j.proenv.2017.03.010

5. UN-Habitat. World Cities Report 2020: The Value of Sustainable Urbanization. United Nations Human Settlements Programme (UN-Habitat); 2020.
6. Bibri SE, Krogstie J, Kaboli A, et al. Smarter eco-cities and their leading-edge artificial intelligence of things solutions for environmental sustainability: A comprehensive systematic review. *Environmental Science and Ecotechnology*. 2024; 19: 100330. doi: 10.1016/j.ese.2023.100330
7. Yndestad H. Smart regions. Available online: <https://www.researchgate.net/publication/274194125> (accessed on 9 March 2024).
8. Bibri SE. Data-driven smart eco-cities and sustainable integrated districts: A best-evidence synthesis approach to an extensive literature review. *European Journal of Futures Research*. 2021; 9(1). doi: 10.1186/s40309-021-00181-4
9. Suzuki H, Dastur A, Moffatt S, et al. Eco2 Cities: Ecological Cities as Economic Cities. World Bank Publications. doi: 10.1596/978-0-8213-8046-8
10. Matern A, Binder J, Noack A. Smart regions: insights from hybridization and peripheralization research. *European Planning Studies*. 2019; 28(10): 2060-2077. doi: 10.1080/09654313.2019.1703910
11. Lécuyer C. Making Silicon Valley. The MIT Press; 2007.
12. Van Ham H, Koppenjan J. Building Public-Private Partnerships: Assessing and managing risks in port development. *Public Management Review*. 2001; 3(4): 593-616. doi: 10.1080/14616670110070622
13. Joo YM, Tan TB (editors). *Smart Cities in Asia*. Springer Nature; 2020.
14. Bakıcı T, Almirall E, Wareham J. A Smart City Initiative: the Case of Barcelona. *Journal of the Knowledge Economy*. 2012; 4(2): 135-148. doi: 10.1007/s13132-012-0084-9
15. Townsend AM. *Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia*. W.W. Norton & Company; 2013.
16. Bibri SE, Huang J, Krogstie J. Artificial intelligence of things for synergizing smarter eco-city brain, metabolism, and platform: Pioneering data-driven environmental governance. *Sustainable Cities and Society*. 2024; 108: 105516. doi: 10.1016/j.scs.2024.105516
17. Naguib D, Afifi M, Wahba S. Towards Sustainability in Eco-cities; TDR and Possibilities of Application on Urban Areas. *Procedia Environmental Sciences*. 2016; 34: 94-103. doi: 10.1016/j.proenv.2016.04.010
18. Fei J, Wang Y, Yang Y, et al. Towards Eco-city: The Role of Green Innovation. *Energy Procedia*. 2016; 104: 165-170. doi: 10.1016/j.egypro.2016.12.029
19. Javidroozi V, Carter C, Grace M, et al. Smart, Sustainable, Green Cities: A State-of-the-Art Review. *Sustainability*. 2023; 15(6): 5353. doi: 10.3390/su15065353
20. Petrea MI, Ursache IM. Inside the world's most sustainable smart city: Lessons from Copenhagen. *European Smart Cities for Sustainable Development*. Available online: <https://www.researchgate.net/publication/374632552> (accessed on 6 March 2024).
21. Quélin B, Smadja I. Smart cities: The sustainable program of six leading cities. The green growth city Copenhagen. Available online: <https://www.hec.edu/sites/default/files/documents/Copenhagen-Smartcities-the-sustainable-program-six-leading-cities-soreport-2021-2%5B4%5D.pdf> (accessed on 6 March 2024).
22. Yang W, Deng W. Building related KPIs in Sino-Singapore Tianjin Eco-City. *APCBEE Procedia*. 2013; 5: 112-115. doi: 10.1016/j.apcbee.2013.05.020
23. Zhao H, Gu B, Chen D, et al. Physicochemical properties and salinization characteristics of soils in coastal land reclamation areas: A case study of China-Singapore Tianjin Eco-City. *Heliyon*. 2022; 8(12): e12629. doi: 10.1016/j.heliyon.2022.e12629
24. Bibri SE. Eco-districts and data-driven smart eco-cities: Emerging approaches to strategic planning by design and spatial scaling and evaluation by technology. *Land Use Policy*. 2022; 113: 105830. doi: 10.1016/j.landusepol.2021.105830
25. Yang X, Zhou Y. Research progress of eco city evaluation. *Eco Cities*. 2021; 2(1): 10. doi: 10.54517/ec.v3i2.1842