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AI and Human-Centric Approach in Smart Cities Management: Case Studies from Silesian and Lesser Poland Voivodships

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Abstract: The presented paper examines the integration of Artificial Intelligence (AI) in the management of smart cities, focusing on the Silesian and Lesser Poland Voivodships in Poland. This research addresses a notable gap in the analysis of regional AI strategies within urban management, providing a comparative analysis of AI implementation in these two distinct regions. The Silesian Voivodship, with its emphasis on traditional industries such as manufacturing and energy, contrasts with the broader approach of the Lesser Poland Voivodship, which includes applications in life sciences and ICT. The paper explores how AI technologies enhance urban efficiency, sustainability, and livability through practical applications in traffic management, healthcare, energy efficiency, and environmental management. It highlights the importance of a human-centric approach in smart city development, emphasizing inclusivity, transparency, and ethical considerations. The paper also delves into the socio-technical dynamics of AI deployment, illustrating how these technologies can transform urban environments while ensuring that the benefits are equitably distributed and that urban developments are sustainable and resilient. By analyzing specific case studies, the authors aim to provide empirical evidence and insights that contribute to the academic and practical understanding of AI's role in smart cities, ultimately advocating for the design of AI applications that prioritize human well-being and environmental health.

Keywords: AI in management; smart city; human-centric smart city; innovations; AI transformation

1. Introduction

The process of industrialization has evolved significantly due to technological advancements, especially through the stages of the Industrial Revolutions. The third revolution, which introduced automation, began in the late 20th century and remains prevalent across various industries. Following this, the fourth industrial revolution, or Industry 4.0, introduced a new style of managing and controlling the entire product lifecycle to cater to individual customer needs. This revolution has influenced multiple facets of industry, such as research and development, design, inventory management, service, and customer care. Industry 4.0 is characterized by the integration of technologies like smart manufacturing, big data analytics, cyber–physical systems, and smart machines, marking a significant shift toward the digitization of manufacturing [1].

A smart city, according to ISO 37122:2019 [2], is defined as a "city that increases the pace at which it provides social, economic and environmental sustainability outcomes and responds to challenges such as climate change, rapid population growth, and political and economic instability by fundamentally improving how it engages society, applies collaborative leadership methods, works across disciplines and city systems, and uses data information and modern technologies to deliver better services and quality of life to those in the city (residents, businesses, visitors), now and for the foreseeable future, without unfair disadvantage of others or degradation of the natural environment".

The European Commission [3] describes smart cities as urban areas that integrate digital technologies to enhance the efficiency and sustainability of traditional networks and services. This concept encompasses not just the use of digital tools for better resource management and reduced emissions but also involves the development of advanced urban transport networks, upgraded facilities for water supply and waste disposal, and more efficient systems for lighting and heating buildings.

Additionally, smart cities aim to provide a responsive city administration, safer public spaces, and cater to the specific needs of an aging population, thereby improving the overall quality of life for their inhabitants and supporting sustainable urban development.

According to the European Commission, the marketplace for smart cities operates across several key interdisciplinary areas:

1. Sustainable urban mobility—enhancing transportation systems to be eco-friendlier and more efficient.
2. Sustainable districts and built environment—developing urban areas to be more sustainable through improved construction and planning.
3. Integrated infrastructures and processes—focusing on synergy between energy, ICT, and transport infrastructures for enhanced service delivery.
4. Citizen focus—prioritizing the needs and involvement of citizens in urban development.
5. Policy and regulation—establishing policies and regulatory frameworks that support smart city initiatives.
6. Integrated planning and management—coordinating various aspects of urban planning and management for better efficiency and effectiveness.
7. Knowledge sharing—facilitating the exchange of information and best practices among stakeholders.
8. Baselines, performance indicators, and metrics—using specific benchmarks and metrics to assess the performance of smart city initiatives.
9. Open data governance—managing open data policies to ensure transparency and accessibility of data.
10. Standards—developing and implementing standards to guide the deployment of technologies and practices in smart cities.
11. Business models, procurement, and funding—innovating in business models and financing mechanisms to support sustainable urban development.

Based on a thorough literature analysis [4–52], we have identified a significant research gap in the analysis of AI strategies within specific regions. This paper addresses the need to systematically evaluate and compare the integration of Artificial Intelligence (AI) within urban management strategies in Polish regions, specifically the Silesian and Lesser Poland Voivodships. While AI is increasingly recognized as a transformative force in smart city development, detailed region-specific studies exploring how different areas implement and benefit from AI technologies in diverse urban contexts are lacking.

This paper aims to fill a critical gap in the literature by providing a comparative analysis of AI strategies between the Silesian and Lesser Poland Voivodships, which exhibit distinct approaches and focus areas. The Silesian Voivodship emphasizes using AI in traditional industries such as manufacturing and energy, while the Lesser Poland Voivodship adopts a broader approach, including applications in life sciences and ICT. This regional comparison is crucial for understanding how localized strategies align with broader trends and the unique challenges and opportunities each region faces.

In this paper, we formulated the following research questions:

- Q1: How does the implementation of AI technologies in smart city management differ between the Silesian and Lesser Poland Voivodships, and what are the region-specific challenges and opportunities?

- Q2: In what ways does a human-centric approach influence the adoption and effectiveness of AI in enhancing urban services, such as traffic management, healthcare, and environmental sustainability, in the Silesian and Lesser Poland Voivodships?
- Q3: What are the socio-technical dynamics involved in the deployment of AI in smart cities, and how do these dynamics affect the inclusivity, transparency, and ethical considerations in the Silesian and Lesser Poland regions?
- Q4: How do AI-driven smart city initiatives contribute to the achievement of sustainable development goals in the Silesian and Lesser Poland Voivodships, particularly in areas such as energy efficiency, waste management, and urban mobility?
- Q5: What are the key factors that determine the success of AI integration in smart city strategies within the context of regional innovation policies in Silesian and Lesser Poland Voivodships?

We explore and analyze the use of AI in smart city management, focusing on how these technologies can enhance urban efficiency, sustainability, and livability while maintaining a human-centric approach. The paper provides empirical evidence from case studies in these regions, demonstrating the practical applications and benefits of AI across various urban sectors, including traffic management, healthcare, energy efficiency, and environmental management. Additionally, the research offers a perspective on underexplored Eastern European regions, contributing to a more comprehensive understanding of global AI adoption trends.

The paper further contributes to the academic and practical understanding of the socio-technical dynamics involved in AI deployment in urban settings, emphasizing the importance of inclusivity, transparency, and ethical considerations in the development of smart cities. The findings can serve as a guide for regional planners and policymakers in similar socio-economic contexts, both in Poland and elsewhere.

2. Artificial Intelligence in Smart Cities Management

Artificial Intelligence (AI) in urban management significantly changes the way cities are planned, managed, and experienced, influencing various sectors including traffic management, emergency services, and energy efficiency. As cities evolve into smart urban environments, the role of AI becomes essential, changing them into more sustainable, efficient, and livable habitats.

Sha et al. [53] underline that cities, in response to growing complexities and rapid urbanization, are increasingly turning to technology to meet their sustainability objectives. Scholars like Batty et al. [54], Kitchin [55], and Bibri and Krogstie [56] highlight the reliance on various digital tools such as ICT, IoT, big data, and AI to enhance urban services, resource monitoring, and citizen engagement. These technologies are instrumental in developing smart urban models, which are critical for achieving Sustainable Development Goals, as noted by Leal Filho et al. [57] and Kabus and Dziadkiewicz [58].

The COVID-19 pandemic has further accelerated the adoption of advanced technologies like surveillance and autonomous systems for municipal management, as mentioned by Allam and Jones [59] and Shorfuzzaman et al. [60]. However, the deployment of these technologies can be disruptive, potentially causing significant disruptions in resource-limited urban areas [61–64].

An analysis by Ingwersen and Serrano-López [65] reveals that Artificial Intelligence (AI) has been integral to smart city research since 2008, significantly contributing to global sustainable development [66–68]. AI enables smarter city solutions with numerous benefits, such as improved water and energy management, enhanced waste handling, and reductions in traffic congestion, noise, and pollution.

A comprehensive analysis of global smart city strategies reveals an emphasis on incorporating AI and robotics into various urban systems, reflecting broader goals for sustainable development and improved urban governance.

The use of Artificial Intelligence (AI) in smart cities is diverse and spans across multiple urban sectors, significantly transforming how cities function and improve the quality of life for their residents [7,69,70]. In automation and decision-making, AI is utilized to streamline administrative tasks, optimize resource allocation, and enhance policy-making through predictive analytics and real-time data analysis [8]. This leads to improved efficiency, cost reduction, and more informed decisions in urban management. In education, AI enhances learning experiences by offering personalized education platforms, intelligent tutoring systems, and automating administrative processes. These technologies provide tailored educational content, simplify administrative tasks, and support data-driven decision-making in schools and universities, thereby improving educational outcomes [48–52].

Smart infrastructure is another critical area where AI plays a significant role. AI-driven solutions are employed in the development and maintenance of energy-efficient buildings, intelligent water management systems, and smart grids. These systems help optimize resource use, reduce environmental impact, and enhance the resilience and sustainability of urban infrastructure [13–17]. In smart mobility, AI contributes to the development of real-time traffic management systems, predictive maintenance for transportation networks, and integrated multimodal transport services. These technologies improve traffic flow, reduce congestion, and increase the efficiency and reliability of urban transportation systems [4,71–73].

Healthcare is a sector where AI's impact is profoundly felt. AI applications include diagnostic tools, predictive analytics for disease management, and personalized treatment plans [17]. These innovations improve diagnostic accuracy, optimize treatment protocols, and enhance patient outcomes while reducing healthcare costs and resource consumption. In the realm of transportation and autonomous vehicles [19,20], AI is the backbone of intelligent transportation systems that facilitate safer and more efficient road transport. By using real-time data and machine learning algorithms, AI supports the navigation of autonomous vehicles, reduces traffic accidents, and optimizes route planning, contributing to the evolution of smart, interconnected transportation networks [45,46].

AI also plays a crucial role in crime detection and prevention [26]. It aids law enforcement through predictive policing, surveillance systems with facial recognition capabilities, and real-time crime mapping [27,28]. These technologies enable agencies to anticipate and respond to criminal activities more effectively, enhancing public safety and security [29]. In environmental management, AI is deployed to monitor air and water quality, manage waste, and predict natural disasters [30]. These systems allow for proactive measures to protect urban ecosystems, ensuring a healthier and more resilient environment for city inhabitants [31].

In smart buildings, AI manages operations like energy consumption, climate control, and security, leading to more efficient building management and reduced operational costs [40]. In the tourism, culture, services, and entertainment sectors, AI enhances visitor experiences through personalized recommendations, virtual tours, and intelligent service systems [26,35]. These applications not only improve user engagement and satisfaction but also optimize service delivery in urban cultural and recreational activities. AI's broad impact across these various smart city areas underscores its vital role in shaping the future of urban living [35,69]. In Table 1, there is a comprehensive description of the potential usage of AI in the various smart city areas.

Table 1. Description of AI usage in selected smart city areas.

Smart City Areas	Description of AI Usage
Automation and Decision-Making [7,8]	AI is used to automate routine administrative tasks, optimize resource allocation, and enhance decision-making processes through predictive analytics and real-time data analysis. These applications help improve efficiency, reduce costs, and support more informed policy-making in urban management.
Education [48–52]	AI technologies enhance learning experiences through personalized education platforms, intelligent tutoring systems, and administrative automation. They provide tailored educational content, streamline administrative tasks, and enable data-driven decision-making to improve educational outcomes and resource management in schools and universities.
Smart Infrastructure [13–17]	AI supports the development and maintenance of smart infrastructure, including energy-efficient buildings, intelligent water management systems, and smart grids. These systems optimize resource use, reduce environmental impact, and enhance the resilience and sustainability of urban infrastructure.
Smart Mobility [4,9–12,71–73]	AI-driven smart mobility solutions include real-time traffic management, predictive maintenance of transportation systems, and integrated multimodal transport services. These technologies improve traffic flow, reduce congestion, and enhance the efficiency and reliability of urban transportation networks.
Healthcare [18–25]	AI applications in healthcare include diagnostic tools, predictive analytics for disease outbreak management, and personalized treatment plans. These technologies enhance diagnostic accuracy, optimize treatment protocols, and improve patient outcomes while reducing healthcare costs and resource use.
Transportation and Autonomous Cars [45–48]	AI powers autonomous vehicles and intelligent transportation systems, facilitating safer and more efficient road transport. These systems use real-time data and machine learning algorithms to navigate, reduce traffic accidents, and optimize route planning, contributing to the development of smart, interconnected transportation networks.
Crime Detection and Prevention [26–30]	AI aids in crime detection and prevention through predictive policing, surveillance systems with facial recognition, and real-time crime mapping. These technologies help law enforcement agencies anticipate and respond to criminal activities more effectively, enhancing public safety and security.
Environmental Management [30–33]	AI technologies support environmental management by monitoring air and water quality, managing waste, and predicting natural disasters. These systems enable proactive measures to protect and sustain urban ecosystems, ensuring a healthier and more resilient environment for city inhabitants.
Smart Buildings [5,40–44]	AI in smart buildings involves energy management systems, automated lighting and climate control, and predictive maintenance. These applications enhance the efficiency and comfort of buildings, reduce operational costs, and contribute to sustainability goals.
Tourism, Culture, Services, and Entertainment [34–38]	AI enhances tourism and cultural experiences through personalized recommendations, virtual tours, and intelligent service systems. In the entertainment sector, AI-driven platforms offer personalized content, enhance user experiences, and optimize service delivery, thereby boosting engagement and satisfaction in urban cultural and recreational activities.

Sources: Authors own analysis on the basis of: [4–52].

3. Human-Centric Smart Cities

Human-centric smart cities prioritize the needs and well-being of their inhabitants through the integration of technology, urban planning, and community engagement. A human-centric smart city is designed with the primary goal of enhancing the quality of life for all its residents, balancing technological advancements with socio-economic benefits and sustainability [74,75].

Human-centric smart cities are founded on the principle that technology should serve people, not the other way around. Customer experience is a primary goal for organizations today [76,77]. Furthermore, organizations are increasingly adopting digital innovations, which have become standard practices in the current business environment, according to Verhoef et al. [78].

The White Paper on AI highlights seven key elements underlying the paramount of societal and environmental well-being. This focus in terms of smart cities stresses that any urban development, particularly in the deployment of AI technologies, must prioritize human-centric approaches. Such strategies ensure that the integration of AI not only advances technological and economic prospects but also enhances the quality of life and sustainability. The directive suggests that cities should design AI applications that support social welfare and environmental health, thereby fostering communities that are not only more efficient but also more livable and inclusive. This approach aligns with the broader objectives of creating smart cities that put the well-being of their inhabitants first [79].

Kitchin [80] defines smart cities as urban areas that leverage digital technology and intelligent design to create responsive, adaptive urban spaces. However, the human-centric approach takes this a step further by ensuring that these technologies are implemented in ways that are directly beneficial to the inhabitants. This includes enhancing accessibility, improving public health, and ensuring economic viability.

In human-centric smart cities, the principles of design focus on inclusivity, sustainability, and resilience. These principles ensure that city services and benefits are accessible to all, including marginalized groups, and that urban environments are sustainable and capable of withstanding various environmental and social stresses [81].

Technologies fundamental to the development of smart cities include the Internet of Things (IoT), which involves devices and sensors interconnected across the city to enhance data collection and management. Big Data Analytics is used to analyze large data sets to improve decision-making and urban planning, while Artificial Intelligence (AI) manages and optimizes city services such as traffic control and waste management [82].

Key components of human-centric smart cities can be grouped as follows:

1. Technology integration: Integral to human-centric smart cities is the seamless integration of IoT devices, which collect and analyze data to improve urban services. For instance, smart sensors can monitor air quality and traffic conditions, improving residents' health and reducing commute times [83].
2. Citizen engagement: Engaging citizens in the planning and implementation of smart initiatives is crucial. By utilizing platforms for civic engagement, cities can ensure that the services developed are in line with the needs and preferences of their residents [84].
3. Sustainability: Sustainable practices are at the heart of human-centric smart cities. Technologies are employed to optimize resource use and reduce environmental footprints, thereby supporting urban sustainability goals [85].

In Table 2, there is a description of the principles of centric smart cities. Human-centric smart cities are designed with the fundamental goal of enhancing the quality of life for all residents by leveraging technology in ways that are inclusive, equitable, and sustainable [86,87]. A key principle is inclusivity and accessibility, which ensures that all individuals, regardless of age, gender, income, or ability, have equal access to the benefits of smart city technologies [88]. This involves designing user-friendly interfaces, providing digital literacy programs, and implementing policies to bridge the digital divide.

Table 2. Description of human-centric smart city principles.

Principle of Human Centric Smart City	Description
Inclusivity and Accessibility	Ensuring that all residents, regardless of age, gender, income, or ability, have equal access to smart city technologies and benefits. This includes designing user-friendly interfaces, providing digital literacy programs, and implementing policies to bridge the digital divide.
Transparency and Accountability	Maintaining open communication and clear information about how data are collected, used, and protected. This involves engaging residents in decision-making processes, providing access to public data, and establishing mechanisms for accountability and redress in case of misuse of technology.
Privacy and Data Protection	Safeguarding personal data and ensuring privacy through robust data protection measures. This principle emphasizes the importance of consent, data minimization, and implementing security measures to prevent unauthorized access and breaches.
Sustainability and Resilience [5,89–93]	Prioritizing environmental sustainability and resilience in urban planning and development. This includes using AI and smart technologies to reduce resource consumption, manage waste, and enhance the city's ability to withstand and recover from environmental, economic, and social challenges.
Community Engagement	Actively involving residents in the planning, development, and implementation of smart city initiatives. This includes conducting surveys, holding public consultations, and fostering collaboration between government, businesses, and citizens to ensure that the technology meets the community's needs.
Equity and Fairness	Promoting social equity by ensuring that the benefits of smart city technologies are distributed fairly and do not exacerbate existing inequalities. This involves targeting investments in underserved areas and addressing potential biases in AI systems that could disadvantage certain groups.
Adaptability and Flexibility	Designing systems and policies that are adaptable to changing needs and technologies. This principle emphasizes the importance of continuous learning, innovation, and the ability to scale solutions to accommodate future growth and evolving urban challenges.
Human Well-being	Focusing on improving the overall quality of life for all residents by enhancing health, safety, and social well-being. This includes leveraging technology to create safer, healthier, and more enjoyable urban environments, and ensuring that human needs and values remain at the core of smart city initiatives.

Source: Authors own analysis on the basis of: [5,86–93].

Transparency and accountability are also crucial principles, as they involve maintaining open communication and clear information about how data are collected, used, and protected [89]. Engaging residents in decision-making processes, providing access to public data, and establishing mechanisms for accountability and redress in case of misuse are essential components of this principle. Privacy and data protection are paramount, requiring robust measures to safeguard personal data and ensure privacy [90]. This includes obtaining consent, minimizing data collection, and implementing security measures to prevent unauthorized access and breaches. Sustainability and resilience are integral to human-centric smart cities, emphasizing environmental sustainability and the city's ability to withstand and recover from environmental, economic, and social challenges. AI and smart technologies are utilized to reduce resource consumption, manage waste, and enhance resilience [91,92].

Community engagement is vital, involving residents in the planning, development, and implementation of smart city initiatives. This principle is realized through surveys, public consultations, and fostering collaboration between government, businesses, and citizens to ensure the technology meets community needs [93]. Equity and fairness ensure that the benefits of smart city technologies are distributed fairly, addressing potential biases in AI systems and targeting investments in underserved areas to avoid exacerbating existing inequalities [87,88]. Adaptability and flexibility are important, as they involve designing

systems and policies that can adapt to changing needs and technologies. Continuous learning, innovation, and scalability are emphasized to accommodate future growth and evolving urban challenges [86,87]. Also, human well-being is the ultimate focus, aiming to improve the overall quality of life by enhancing health, safety, and social well-being [86,87]. Smart city initiatives must prioritize human needs and values, leveraging technology to create safer, healthier, and more enjoyable urban environments.

Case studies such as Barcelona and Singapore illustrate the application of these technologies. Barcelona has implemented extensive IoT systems to enhance public transportation and waste management, significantly improving urban living standards [94]. In Singapore, the smart nation initiative focuses on healthcare, transportation, and public services, employing AI and big data to cater to the aging population's needs [95].

In smart cities, Green Innovation (GI) and Responsible Leadership are key to sustainable development. GI involves adopting environmentally friendly technologies that improve organizational performance and promote sustainability [96]. Responsible Leadership focuses on ethical behavior and stakeholder engagement to foster environments where GI thrives. It ensures policies support sustainable practices and technological advancements align with environmental goals [97]. Studies like Liao and Zhang [98] show that such leadership enhances environmental performance through innovation, motivating behaviors that support both community well-being and environmental sustainability.

Ethical considerations in human-centric smart cities include issues of privacy, ensuring the protection of personal data against misuse; equity, ensuring equitable access to technology and its benefits; and transparency, maintaining openness in how data are used and decisions are made [99,100]. Additionally, there is a risk of widening the digital divide, as not all residents may have equal access to the technologies employed [101]. To address these issues, it is essential to implement strict data protection regulations and ensure that initiatives to bridge the technology gap are part of smart city planning [101].

Moreover, continuous monitoring and adaptation of strategies in response to feedback and technological advancements can help mitigate these challenges [102].

In conclusion, human-centric smart cities represent a shift towards integrating technology into urban environments that prioritize human values and needs. As these cities evolve, continuous assessment and integration of ethical considerations are crucial to ensure they remain centered on enhancing residents' quality of life.

4. Methodology

The methodology employed in the study on smart cities primarily involves desk research, using existing data from a range of sources to construct an analysis of the smart city market and its trends.

The regions of Silesia and Lesser Poland were selected due to their prominent roles in regional innovation and smart city initiatives, with a particular emphasis on AI management and regional development as outlined in the "Regional Innovation Strategy of the Silesian Voivodeship 2030" and the "Regional Innovation Strategy of the Lesser Poland Voivodeship 2030". These regions provide a coherent framework for examining local governance, economic, and technological dynamics in relation to smart city development, allowing for a nuanced comparative analysis within a shared national and EU policy context. Additionally, focusing on these regions permits observing how mid-sized European regions, which are increasingly important players in innovation, address AI management and smart city solutions.

The primary document analyzed is the "Special report, smart cities, tangible solutions, but fragmentation challenges their wider adoption", which provides an overview of current challenges and opportunities within the smart city sector.

This report is supplemented by quantitative data and forecasts from authoritative sources such as Statista.com and Grand View Research, offering detailed market projections and growth rates. These sources are instrumental in providing a comparative perspective on regional developments and technological advancements.

The main objective of the research is to analyze how the "Regional Innovation Strategy of the Silesian Voivodeship 2030" and the "Regional Innovation Strategy of the Lesser Poland Voivodeship 2030", along with the smart city initiatives in Katowice and Kraków, are implemented and their potential impacts on regional development and AI management.

The analysis begins with a detailed review of the source materials, which include the two regional strategies and supplementary materials from the Invest in Katowice and Kraków Smart City strategy documents. The content of these documents is systematically examined to identify goals, planned actions, expected outcomes, and strategic focuses across different sectors such as energy, medicine, ICT, emerging industries, green economy, and smart city solutions.

A comparative analysis is conducted between the strategies and initiatives across both voivodships and their respective main cities. This comparison helps to identify unique and shared elements in how each region or city approaches innovation in similar sectors. Additionally, the analysis examines the alignment between strategic goals and detailed implementation plans, considering potential barriers within the regional economic and social contexts.

Thematic analysis further aids in identifying sector-specific themes within each specialization area, focusing on aspects like investment priorities, technology adoption, and collaboration frameworks. Cross-cutting themes that span multiple sectors, such as sustainability, digital transformation, and public–private partnerships, are also explored to understand overarching strategic orientations.

The findings from the document and thematic analyses are integrated to construct a coherent picture of how regional innovation strategies are positioned to influence the innovation ecosystems. This report not only outlines the strengths and potential gaps in the strategies but also discusses the implications for future policy-making.

The implications section of the report focuses on recommendations for enhancing the effectiveness of current strategies and suggests areas for further research, such as longitudinal studies, to track the strategies' implementation and impact over time.

4.1. Smart Cities—Statistics

The report called "Special report, smart cities, tangible solutions, but fragmentation challenges their wider adoption" on smart cities underscores the pressing need for research and innovation investment to harness technology in improving city management. This approach aligns with three of the European Union's priorities: advancing the Green Deal, focusing on digital technology, and promoting an economy that benefits people. Urban areas, which are home to nearly 75% of EU citizens—a figure projected to rise to 80% by 2050—are significant contributors to environmental issues, including emissions and pollution.

Smart cities aim to mitigate these problems by integrating new, efficient technologies and services in energy, transport, and ICT. These technologies not only enhance resource efficiency and pollution reduction but also aim to make urban services more responsive and public spaces safer. Achieving these goals requires the implementation of innovative technologies, new business models, effective management practices, and supportive governance structures, all underpinned by robust investment in research and innovation.

According to Statista.com, Poland's Smart Cities market is poised for significant growth and is projected to reach a revenue of USD 0.63 billion by 2024. This upward trend is expected to maintain an annual growth rate of 12.52% from 2024 to 2028, culminating in a market volume of USD 1.01 billion by the end of 2028. In a global comparison, China is expected to lead the Smart Cities market, with an anticipated revenue of USD 43,550.00 million in 2024. Poland's investment in smart city solutions aims to enhance urban infrastructure and improve the quality of life for its citizens.

The statistics of Grand View Research state that the smart cities market is projected to reach a significant size by 2030, growing at a compound annual growth rate (CAGR) of 25.8% from 2023 to 2030. This growth is driven by several factors, including the integration

of advanced technologies like Artificial Intelligence (AI), the Internet of Things (IoT), and big data analytics. These technologies are being adopted globally to improve infrastructure management, enhance public safety, and promote environmental sustainability (Grand View Research).

Key segments within the smart cities market include smart utilities, smart transportation, and smart governance. Smart utilities, which dominate the market, focus on energy management and efficient resource distribution, such as water and waste management. The intelligent transportation segment is also significant, aiming to reduce traffic congestion and pollution through advanced traffic management systems and smart parking solutions (Grand View Research; Astra ESG Solutions).

Regionally, North America is a major player in the smart cities market, thanks to its advanced ICT infrastructure and collaborative efforts between government and technology providers. The market in Asia Pacific is expected to grow rapidly, fueled by economic development, digitalization, and urbanization, particularly in countries like China, Japan, and India (Grand View Research; Astra ESG Solutions).

The market's expansion is supported by various government initiatives and the growing demand for sustainable development aligned with the United Nations' Sustainable Development Goals (SDGs). This has encouraged a focus on innovative and sustainable solutions across different sectors of urban development (Grand View Research; Astra ESG Solutions).

4.2. Silesian Voivodship and Innovations

The document "Regionalna Strategia Innowacji Województwa Śląskiego 2030" (Regional Innovation Strategy of the Silesian Voivodeship 2030) for the Silesian Voivodship focuses on the intelligent specializations in the specified branches:

1.   Intelligent specialization—Energy

The document highlights an emphasis on renewable energy sources and energy efficiency to meet the EU's goal of climate neutrality by 2050. It outlines significant investments in both public and private sectors, including the development of wind and nuclear energy. The regional strategy aims to integrate energy management systems and enhance infrastructure to support research and development in energy sectors.

2.   Intelligent specialization—Medicine

The strategy acknowledges the low proportion of healthcare spending relative to GDP in Poland and emphasizes improving healthcare services and infrastructure. It targets innovative medical technologies, particularly in cardiology, oncology, and telemedicine. There is a focus on integrating medical research institutions and businesses to foster innovative health solutions, with an aim to increase investment in research and development and to promote local and international collaborations.

3.   Intelligent specialization—Information and Communication Technologies (ICT)

This section outlines plans to strengthen the ICT sector by supporting startups and established companies in software development, Artificial Intelligence, and the Internet of Things (IoT). The strategy includes enhancing ICT education and training, boosting infrastructure, and promoting digital transformation across various sectors including healthcare, energy, and public services.

4.   Intelligent specialization—Emerging Industries

The focus here is on industries that are expected to grow significantly due to technological advancements. The document lists areas such as creative industries, mobility industries, and industries involving new materials and smart manufacturing processes. There is an emphasis on fostering innovation through clusters and partnerships between universities, research institutions, and the business community.

5.   Intelligent specialization—Green Economy

The green economy section stresses the importance of sustainable development, including the management of natural resources and the reduction of environmental impacts. It advocates for innovations that support economic activities that are not only environmentally friendly but also economically viable and socially inclusive. The strategy highlights the importance of transitioning to a circular economy and increasing the region's resilience to environmental challenges.

Overall, the document presents a strategic vision for Silesian Voivodship's development, focusing on modernizing the region's economic base through innovation and specialized sectors that leverage local strengths and address global challenges.

Katowice Smart City

The Invest Katowice website is a prime example of how a city can present itself as a modern, smart city with high economic potential. Katowice has invested in becoming a smart city through various innovative approaches. This includes the implementation of intelligent transportation systems, energy-efficient buildings, and widespread digital services to enhance public services and urban management. The city focuses on sustainable development and the use of advanced technology to improve the lives of its residents and the efficiency of its infrastructure.

Katowice's economic landscape is highly diversified, featuring a broad spectrum of industries including culture, education, medicine, commerce, banking, energy, construction, pharmacy, food industry, automotive industry, engineering design, transport and logistics, machine industry, IT, mining, and metallurgy. This diversity is a crucial economic advantage for the city.

According to Invest Katowice website, the MSME (Micro, Small, and Medium Enterprises) sector dominates the business environment in Katowice, comprising about 99% of all business entities in the city, equating to 55,025 entities according to the CSO of Poland as of November 2023. These enterprises are predominantly engaged in trade, education, construction, industrial processing, and professional, scientific, and technical activities, creating significant job opportunities.

Katowice, along with the Metropolis GZM, ranks among the top five centers for modern business services in Poland, which includes Business Process Outsourcing (BPO), Shared Services Centers (SSC)/Global Business Services (GBS), IT, and Research and Development (R&D) sectors. Notably, these centers employ 32,000 people, marking a 60% growth in employment from 2018 to 2023, with a significant majority (92.4%) of the employment concentrated in Katowice. The business services centers in Katowice host international firms predominantly from the USA, France, Germany, the UK, and the Netherlands, with these countries accounting for nearly 60% of all centers. The IT sector leads in service provision and employment within these centers.

Business tourism also plays an essential role in Katowice's economic development, supported by significant infrastructure such as the Culture Zone, NOSPR (one of the world's best concert halls), the International Congress Centre, and the Silesian Museum. In 2022, Katowice hosted 6426 business events, with a notable portion lasting two days or longer. The city offers 25 hotels with accommodations for 4987 guests and extensive conference facilities, underscoring its capability to handle large-scale events and conferences. This infrastructure and activity generated substantial revenue, with total expenses from conference participants amounting to approximately PLN 151.27 million.

In terms of smart cities, on the Invest Katowice website, it is stated that Katowice is making significant strides as a leader in electromobility and smart city solutions in Poland, emphasizing sustainable and intelligent transport systems. The city's public transportation includes an extensive tram network and electric buses. It also supports electric and shared vehicles, such as cars and scooters, enhancing last-mile connectivity and multimodal transport options. Furthermore, Katowice has invested in an advanced smart city infrastructure, including:

- Intelligent LED Lighting System: Enhancing energy efficiency across the city.
- Low-Emission Economy Plan: A strategic document guiding sustainable and low-emission energy management.
- KISMiA (Katowice Intelligent Monitoring and Analysis System): Using 274 cameras to monitor and manage city traffic and safety effectively.
- AWAIR: The largest air monitoring network in Poland, with 127 sensors providing real-time data on air quality, displayed on 154 screens around the city.
- Śląska Karta Usług Publicznych (ŚKUP): A multipurpose card that facilitates payments for public transport, parking, and other services.

Additionally, the city has established four modern integrated transport hubs within the park and ride system, providing over 1100 parking spaces and 147 charging points for electric vehicles, with plans for more.

Katowice's commitment to smart, sustainable solutions is set to enhance urban living significantly, providing greater comfort and convenience for its residents and foreseeably leading to more innovative developments in the future.

The city emphasizes a human-centric approach in its smart city initiatives. This approach prioritizes the needs and well-being of its citizens through participatory decision-making processes, ensuring that technological advancements contribute positively to everyday life. The development of smart solutions in public transportation, healthcare, and housing is completed with significant input from residents, reflecting a model that values citizen engagement and well-being.

Overall, Katowice presents itself as a dynamic and evolving city that integrates technology and innovation with the needs of its citizens, making it an attractive location for both living and doing business. Its commitment to sustainable development and smart city solutions, paired with a strong economic foundation and high living standards, positions Katowice as a leading city in Europe for investors and residents alike.

4.3. Lesser Poland Voivodship and Innovations

The fourth chapter of the document, "Regional Innovation Strategy of the Lesser Poland Voivodship 2030" details the analysis of Lesser Poland's smart specializations in various sectors. Here is a summary for each mentioned branch:

1. Life Science:

This sector in Lesser Poland focuses on medical and pharmaceutical industries, emphasizing innovation in patient care through Big Data and AI technologies. The region has seen significant investments in virtual health and telemedicine. Collaborative efforts are highlighted, including partnerships that leverage the University Hospital and local universities to boost research and commercialization in life science technologies.

2. Sustainable Energy:

The energy sector is committed to sustainable and renewable energy sources. The strategy focuses on developing and promoting energy-efficient technologies and practices, aiming for a large-scale implementation. The region supports educational initiatives and public campaigns about renewable and distributed energy, emphasizing the importance of sustainability in the energy sector.

3. Information and Communication Technologies (ICT):

This domain is recognized for its broad application across other sectors, including healthcare, banking, and public administration. Companies like Comarch and Luxoft exemplify the region's strengths in providing ICT services across various fields. There is an emphasis on developing ICT solutions that are market complementary and can be utilized across different sectors.

4. Chemistry:

The chemical sector in Lesser Poland is interconnected with healthcare, agriculture, energy, and waste management. There is a focus on the production of chemicals, phar-

maceutical substances, and environmental technologies. The region has experienced a decrease in the dynamism of its chemical industry relative to national trends, prompting strategies to revitalize its growth and development.

5. Production of Metals and Metal Products:

This sector includes companies engaged in the manufacture of raw materials, metal products, and non-metallic mineral products. There is significant foreign investment, notably from ArcelorMittal, and collaboration with local technical universities to support innovation in materials engineering and advanced manufacturing processes.

6. Electrotechnics and Machinery Industry:

This sector is highly innovative and significantly contributes to Lesser Poland's exports. It focuses on the production of electrical and electronic equipment, machinery, and automotive components. The region's strategy emphasizes enhancing the international competitiveness and innovation capacity of this sector.

7. Creative Industries and Leisure Time:

This broad domain includes cultural industries, design, video game production, and premium tourism linked with modern ICT solutions. There is a strong emphasis on using the region's cultural and natural resources and promoting health and wellness services as part of the leisure industry.

Kraków Smart City

Kraków's development strategy by 2030/2050 embraces a comprehensive smart city concept aimed at enhancing urban living through innovative integration of technology in public governance and urban infrastructure. This vision is reflected through its strategic objectives, which include advancements in smart economy, smart living, smart mobility, and smart environment. These aspects are described as follows:

Smart Economy—Kraków aims to foster a dynamic economic environment supported by modern services, research and development sectors, and creative industries. The city plans to strengthen its role as a central hub for business and innovation, enhancing the labor market's flexibility and fostering collaboration between academia and industry.

Smart People—the strategy highlights the role of Kraków's residents as key drivers of change, emphasizing the importance of high educational standards and skills to support continuous improvement in quality of life.

Smart Living—Kraków is committed to providing a high-quality living environment with extensive access to public services, including digital services, healthcare, education, and elder care. The city prioritizes safety, cultural vibrancy, and recreational opportunities to enhance the well-being of its citizens.

Smart Mobility—with a focus on integrated and sustainable transport solutions, Kraków intends to develop efficient transportation networks that leverage information and communication technologies, improving connectivity and reducing environmental impact.

Smart Environment—the city's environmental strategy is geared towards optimizing energy usage, reducing emissions, and promoting sustainable resource management. Kraków aims to adapt to climate change while improving the quality of its natural environments.

Smart Governance—Kraków's governance model emphasizes transparency, citizen participation, and high-quality public services. The city plans to implement an integrated management system that includes all stakeholders in the smart city objectives, ensuring effective public–private partnerships.

This strategic approach not only aims to position Kraków as a leading smart city but also as a vibrant, innovative, and sustainable European metropolis, making it an attractive destination for residents, businesses, and tourists alike.

4.4. Silesian and Lesser Poland—Innovations and AI Management

The rapid development of Artificial Intelligence (AI) technologies presents unique opportunities for regional development and economic enhancement. As part of the broader

strategic initiatives within Poland, the Silesian and Lesser Poland Voivodships have embarked on ambitious programs to integrate AI into their industrial, economic, and social frameworks.

This section analyses the specific AI integration strategies employed by these two regions, examining their focus areas, implementation strategies, challenges faced, and the resultant economic impacts and sustainability efforts. In the Silesian Voivodship, the focus is primarily on incorporating AI within traditional industrial sectors, such as manufacturing and energy, while also enhancing urban mobility through smart city solutions. Conversely, Lesser Poland Voivodship employs a broader AI application spectrum, targeting sectors like life sciences, sustainable energy, and ICT, and emphasizes the development of digital innovation hubs.

This analysis highlights the distinct yet complementary approaches adopted by each voivodship in using AI to foster growth and sustainability, reflecting their unique regional strengths and strategic priorities. Through this comparative examination, we aim to show how regional policies can be tailored to harness the transformative potential of AI, thereby enhancing our understanding of regional innovation ecosystems in terms of digital transformation what is depicted in Table 3.

Table 3. AI integration strategies in the Silesian and Lesser Poland Voivodships: own study.

Aspect	Silesian Voivodship	Lesser Poland Voivodship
Focus Areas	- Integration of AI in industrial frameworks, especially manufacturing and urban mobility	- Broad AI applications in life sciences, sustainable energy, ICT
	- Smart city solutions: digital public services, sustainable urban planning	- Development of digital innovation hubs for SMEs and industrial use
Implementation Strategies	- Projects and partnerships focusing on competitive traditional industries like manufacturing and energy	- Educational and infrastructural enhancements for AI and digital transformation
	- Strategic use of digital platforms and hubs for AI integration in public services and industry	- Collaborative approach with businesses, academia, and government
Challenges and Solutions	- Adapting to digital landscape, preparing workforce for new technologies	- Integrating diverse sectors into a cohesive digital and AI strategy
	- Partnerships for knowledge transfer and skill development	- Creation of specialized hubs and networks for AI development and diffusion
Economic Impact and Sustainability	- AI enhances efficiency in traditional industries, potential for smart, energy-efficient urban environments	- Focus on creating new economic opportunities, enhancing international competitiveness
	- Link between AI and development of technologically integrated, energy-efficient environments	- AI-driven development of green technologies and energy solutions

The analysis of AI usage strategies in the Silesian and Lesser Poland Voivodships reveals distinct yet complementary approaches in their focus areas, implementation strategies, challenges, and economic impacts.

In the Silesian Voivodship, the primary focus lies in the implementation of AI within industrial frameworks, especially manufacturing and urban mobility. This region prioritizes smart city solutions, emphasizing digital public services and sustainable urban planning. The implementation strategies involve projects and partnerships centered on traditional industries such as manufacturing and energy.

The strategic use of digital platforms and hubs facilitates AI integration in public services and industry, enhancing efficiency and productivity. The primary challenges include adapting to digital transformation and preparing the workforce for new technologies. Solutions include forming partnerships for knowledge transfer and skill development. The economic impact is significant, with AI enhancing efficiency in traditional industries and

the potential to create smart, energy-efficient urban environments. This link between AI and the development of technologically integrated, energy-efficient environments highlights the region's commitment to sustainable urban growth.

Conversely, Lesser Poland Voivodship adopts a broader approach to AI applications, focusing on life sciences, sustainable energy, and ICT. This region is dedicated to developing digital innovation hubs for SMEs and industrial use. Implementation strategies include educational and infrastructural enhancements to support AI and digital transformation. A collaborative approach involving businesses, academia, and government is central to their strategy.

The main challenges involve integrating diverse sectors into a cohesive digital and AI strategy. Solutions include creating specialized hubs and networks for AI development and diffusion. Economically, Lesser Poland emphasizes creating new opportunities and enhancing international competitiveness through AI. This region's focus on AI-driven development of green technologies and energy solutions aligns with its sustainability goals, fostering innovation in environmentally friendly technologies.

Both regions demonstrate a commitment to leveraging AI for economic and technological advancements. Silesian Voivodship's focus on traditional industries and urban mobility complements Lesser Poland Voivodship's broader approach to diverse sectors, life sciences, and sustainable energy. Together, these strategies contribute to the comprehensive digital and AI transformation of these regions, promoting economic growth and sustainability.

5. Discussion

The paper provides a comprehensive analysis of how AI integration impacts urban management in these regions. The findings underscore the substantial role AI plays in various sectors, such as traffic management, energy efficiency, public services, healthcare, and environmental management, demonstrating a significant positive transformation towards more sustainable, efficient, and livable urban environments.

The analysis of AI's application in smart cities reveals that its integration leads to improved urban services and resource management. For instance, in traffic management, AI systems enable real-time monitoring and control, which helps in reducing congestion and improving traffic flow [5,92]. This results in lower emissions and enhanced air quality, contributing to the overall environmental sustainability of urban areas.

In terms of energy management [8], the implementation of AI-driven systems allows for more efficient energy consumption and distribution [30,31]. The use of predictive analytics and automated systems helps in balancing supply and demand, thus reducing waste and lowering costs. This efficiency is particularly crucial in achieving the EU's climate neutrality goals by 2050, as highlighted in the regional strategies of the Silesian Voivodship.

Healthcare in smart cities benefits significantly from AI through improved diagnostic accuracy and personalized treatment plans [19–22]. AI's ability to analyze vast amounts of data and identify patterns aids in early disease detection and effective treatment planning [23]. This not only enhances patient outcomes but also reduces the overall burden on healthcare systems. The Silesian Voivodship's emphasis on innovative medical technologies, especially in cardiology, oncology, and telemedicine, illustrates the region's commitment to leveraging AI for better healthcare services.

Environmental management is another critical area where AI's impact is evident. AI technologies enable better monitoring and management of natural resources, waste, and pollution [30,31,92]. The use of AI in water quality monitoring and waste classification, for example, helps in maintaining sustainable urban ecosystems [32]. These technologies also play a vital role in disaster detection and response, thereby increasing the resilience of cities to environmental challenges.

Also, the importance of a human-centric approach in smart city development should be addressed. It is emphasized that while technological advancements are crucial, the primary goal should be to enhance the quality of life for all residents [86–89]. This involves

ensuring equitable access to technology and its benefits, fostering community engagement, and maintaining transparency and ethical standards in the deployment of AI systems. The principles of inclusivity, sustainability, and resilience are fundamental to this approach, ensuring that smart city initiatives are designed to serve the needs of all inhabitants, including marginalized groups [85]. Also, the paper discusses the economic benefits of AI integration in smart cities. By improving efficiency and reducing operational costs, AI contributes to regional economic growth [91]. The case studies from Katowice and Kraków demonstrate how AI-driven smart city strategies can attract investment, create jobs, and promote innovation. The regional innovation strategies highlight the potential for AI to drive economic development through sectors like energy, medicine, and ICT.

The results also indicate some challenges and potential barriers to the successful implementation of AI in smart cities. These include issues related to data privacy, the digital divide, and the need for robust regulatory frameworks. Addressing these challenges requires continuous monitoring, adaptation of strategies, and strong policy support to ensure that AI technologies are deployed in ways that are ethical and beneficial to all residents.

The discussion of results through the lens of Socio-Technical Systems Theory (STST) offers a nuanced understanding of how AI technologies are interwoven with social structures and processes to create transformative impacts on urban management. Socio-Technical Systems Theory (STST) posits that successful technological systems must consider both the social and technical components, emphasizing the interplay between human actors, technology, and organizational structures [103–107]. In the context of smart cities, this theory is crucial for understanding how AI not only serves technical functions but also affects and is affected by the social dynamics of urban environments.

The integration of AI in traffic management exemplifies the socio-technical approach. AI systems enable real-time monitoring and adaptive control of traffic signals, which can significantly reduce congestion and optimize traffic flow. These technical advancements have direct social benefits, including reduced travel times, lower emissions, and improved air quality. For example, the implementation of AI in Katowice's traffic management system has led to smoother traffic flows and a reduction in urban air pollution, thus enhancing the quality of life for residents. The success of these systems depends on their acceptance and proper usage by the population, including drivers adhering to new traffic patterns and pedestrians adjusting to changes in traffic light timings. This interplay illustrates the socio-technical nature of AI systems in urban traffic management, where technological improvements are deeply intertwined with human behaviors and societal outcomes [108,109].

AI's role in energy management within smart cities is another area where STST provides valuable insights. AI-driven systems for energy consumption and distribution employ predictive analytics to balance supply and demand, minimizing waste and reducing costs. The Silesian Voivodship's adoption of AI for smart grids is a prime example of how technology and social structures interact. These systems not only enhance technical efficiency but also require changes in user behavior and organizational practices to fully realize their potential. For instance, residents and businesses need to adapt to new pricing models and energy-saving practices promoted by AI-driven insights. The socio-technical perspective emphasizes that the success of these systems relies on user engagement and the alignment of technological solutions with societal values and behaviors [110,111]. This alignment is crucial for achieving the EU's climate neutrality goals by 2050, as AI can significantly contribute to reducing carbon footprints if integrated effectively within the socio-technical framework of urban living.

In healthcare, AI's integration reflects the socio-technical interdependencies where technology enhances human capabilities and social systems influence technological adoption. AI systems improve diagnostic accuracy and enable personalized treatment plans, particularly in specialties like cardiology and oncology, as seen in the healthcare initiatives of the Silesian Voivodship. It can be observed that the deployment of AI in healthcare is

not merely a technical challenge; it involves addressing social factors such as patient trust, data privacy, and the readiness of medical professionals to integrate AI into their practices. The socio-technical approach underscores that the efficacy of AI in healthcare depends on the seamless integration of advanced technologies with the skills, attitudes, and behaviors of healthcare providers and patients [109,110].

Environmental management in smart cities also benefits from the socio-technical perspective. AI technologies for monitoring and managing natural resources, waste, and pollution illustrate how technical systems and social practices must coalesce to create sustainable urban environments. In Lesser Poland, AI-driven systems for water quality monitoring and waste classification help maintain ecological balance and urban sustainability. The socio-technical approach emphasizes that for these AI systems to be effective, they must be integrated into the broader social and regulatory frameworks governing environmental management. Public awareness, community involvement, and regulatory support are essential for the successful deployment and acceptance of AI technologies aimed at environmental sustainability.

The Technology Acceptance Model (TAM) explains how users come to accept and use technology, emphasizing perceived usefulness and perceived ease of use as primary factors influencing technology adoption [112–114]. The discussion reveals that for AI technologies to be successfully integrated into smart city management, they must be perceived as beneficial and user-friendly by residents and stakeholders. The results indicate that AI applications in smart cities are generally well-received due to their ability to improve efficiency and quality of life. For instance, AI systems that enhance traffic management, healthcare, and public services are likely to be embraced if they are seen as effectively addressing urban challenges and are easy to use.

The human-centric approach highlighted in the paper aligns with TAM, as it stresses the importance of designing AI systems that are accessible and equitable [115–117]. Ensuring that AI technologies are user-friendly and provide tangible benefits to all city residents, including marginalized groups, can enhance acceptance and facilitate smoother integration. This approach also involves fostering community engagement and maintaining transparency, which are crucial for building trust and acceptance of AI-driven initiatives.

The case study presented in the article highlights several important lessons for the management of smart cities, not only for other regions in Europe but also for broader global contexts. One significant contribution is the detailed analysis of how Artificial Intelligence (AI) can be strategically integrated into urban management, offering insights into the technological transformation of cities toward sustainability, efficiency, and improved quality of life. By comparing two distinct regions in Poland—Silesian and Lesser Poland Voivodships—the study underscores the importance of tailoring AI applications to regional economic and industrial contexts, a lesson that can be applied globally, particularly in regions with diverse socio-economic conditions.

The important lesson is the value of adopting a human-centric approach in smart city management. This approach prioritizes inclusivity, transparency, and ethical considerations when implementing AI technologies, ensuring that they benefit all citizens equitably. For other regions, this emphasizes the importance of citizen engagement in the decision-making process and the necessity of designing systems that are accessible and adaptable to the needs of all inhabitants, particularly marginalized groups. The focus on ethical AI deployment, which includes safeguarding privacy and preventing biases, is critical for fostering public trust, a challenge faced by many smart city initiatives worldwide.

The study also illustrates how AI can significantly enhance various urban sectors, such as traffic management, healthcare, energy efficiency, and environmental sustainability. For example, AI-driven traffic management systems in Katowice reduce congestion and improve air quality, while AI applications in healthcare offer personalized treatment and diagnostic tools, improving patient outcomes. This demonstrates how smart cities can leverage AI to solve complex urban challenges, such as reducing emissions and optimizing energy consumption, aligning with the Sustainable Development Goals (SDGs). The

emphasis on aligning AI solutions with local needs, whether industrial or environmental, provides a replicable model for other cities seeking to enhance sustainability and livability.

The comparative analysis of the Silesian and Lesser Poland Voivodships reveals the significance of region-specific strategies. Silesian's focus on integrating AI into traditional industries like manufacturing contrasts with Lesser Poland's broader emphasis on life sciences and ICT. This distinction highlights the importance of aligning AI technologies with the region's economic strengths and development goals. For other regions, especially in Europe, this suggests the need for flexible strategies that account for local industries and socio-economic conditions. The adaptability of AI applications is crucial for regions aiming to integrate these technologies into both emerging and established sectors.

Also, an important contribution is the discussion of socio-technical dynamics in smart cities. The successful deployment of AI involves not just technological advancements but also changes in social structures, governance models, and public–private partnerships. The study highlights the need for strong collaboration between government, academia, and the private sector, as seen in both regions, which is crucial for overcoming challenges related to infrastructure, workforce readiness, and regulatory frameworks. This is a valuable lesson for regions where the digital transformation of cities requires extensive coordination among diverse stakeholders.

6. Future Implications for Policy-Making

Based on the analysis of the "Regional Innovation Strategy of the Silesian Voivodeship 2030" the "Regional Innovation Strategy of the Lesser Poland Voivodeship 2030", and the smart city initiatives of Katowice and Kraków, several implications can be drawn for future policy-making. These implications are geared towards enhancing the effectiveness and reach of current strategies, ensuring they more fully support regional innovation and development in order to:

1. Enhance inter-regional collaboration—future policies should foster increased collaboration between different voivodships, particularly in areas of common interest such as ICT, green economy, and smart city solutions. Shared platforms for innovation can be created, facilitating the exchange of best practices and leveraging synergies between regions. This could include joint research initiatives, shared infrastructure projects, and collaborative funding programs.

2. Focus on scalability and replicability—strategies should include clear pathways for scaling successful initiatives and replicating them in different contexts within the regions. This approach will maximize the impact of innovative projects and ensure that successful models contribute to broader regional development.

3. Strengthen links between academia and industry—policies need to continue and strengthen the integration of academic research with industry needs. This could be facilitated by incentivizing R&D projects that involve partnerships between universities, research institutions, and local businesses, particularly in strategic sectors like medicine and advanced manufacturing.

4. Increase investment in key technologies—given the emphasis on sectors like ICT and emerging technologies across the strategies, increased funding, and support should be directed towards these areas. This includes supporting startups and SMEs through grants, loans, and incubation services, and also investing in educational programs to build a skilled workforce adept in these technologies.

5. Improve regulatory frameworks—future policies should aim to streamline and simplify regulatory processes that affect innovation. This includes reducing bureaucratic hurdles for new businesses, speeding up the approval processes for new technologies, and ensuring that regulations keep pace with technological advancements.

6. Promote sustainability and environmental goals—all strategies emphasize sustainability; policies should integrate environmental goals with economic development strategies. This includes promoting energy efficiency, supporting the transition

to renewable energy sources, and implementing stricter environmental standards for industries.

7. Expand digital infrastructure—to support the growth of ICT and smart city solutions, there is a need for expanded digital infrastructure. Future policies should prioritize investments in high-speed internet access, digital services, and smart technology integration in public services to ensure widespread benefits.

8. Foster public engagement and communication—enhancing public engagement in the planning and implementation of innovation strategies can lead to more effective and inclusive outcomes. Policies should encourage regular communication between policymakers, businesses, and the community, ensuring that all stakeholders have a voice in shaping regional development.

9. Monitor and evaluate impact—finally, there is a need for robust mechanisms to monitor and evaluate the impact of implemented strategies. This will not only assess the effectiveness of specific initiatives but also provide valuable feedback for refining and adjusting policies over time.

These implications aim to guide policymakers in refining and enhancing the strategic approach to innovation within the Silesian and Lesser Poland Voivodships and their major cities, ensuring that they are well-positioned to foster economic growth, technological advancement, and sustainable development.

7. Conclusions

The discourse on smart cities involves a diverse range of strategies and initiatives aimed at enhancing urban living through the deployment of innovative technologies. The "Special report, smart cities, tangible solutions, but fragmentation challenges their wider adoption", underscores the need for substantial investment in research and innovative practices to improve city management, aligning with the European Union's Green Deal, digital technology, and economically beneficial strategies. The role of urban areas as significant contributors to environmental issues necessitates the implementation of new and efficient technologies across energy, transport, and ICT sectors to mitigate these impacts.

Poland's Smart Cities market is set for considerable growth, with projections indicating a rise to USD 1.01 billion by 2028, driven by technological advancements such as AI, IoT, and big data analytics. These technologies are crucial for improving infrastructure management, enhancing public safety, and promoting environmental sustainability. Regionally, North America leads, while Asia Pacific is expected to see rapid growth due to its ongoing economic development, digitalization, and urbanization.

In the Silesian Voivodship, the Regional Innovation Strategy focuses on sectors such as energy, medicine, ICT, emerging industries, and the green economy. The strategy is designed to foster innovation and specialized sectors that leverage local strengths to address global challenges. Similarly, Katowice's smart city initiatives highlight a commitment to sustainable and intelligent transport systems and infrastructure improvements, enhancing the quality of life and economic diversity.

The Lesser Poland Voivodship emphasizes innovations in life sciences, sustainable energy, and ICT, aiming to integrate these technologies to enhance regional competitiveness and sustainability. Kraków's comprehensive strategy aims to create a vibrant, innovative, and sustainable urban environment through enhanced public governance and infrastructure.

The realization of the aim to provide empirical evidence and insights from specific case studies in the Silesian and Lesser Poland Voivodships is meticulously achieved through a comprehensive analysis of AI applications across various urban sectors. The paper's approach involves in-depth case studies of these two regions, illustrating how AI technologies are implemented and the benefits they bring to traffic management, healthcare, energy efficiency, and environmental management.

The implementation of AI technologies in smart city management differs notably between the Silesian and Lesser Poland Voivodships due to their distinct industrial profiles and strategic priorities (Q1). In the Silesian Voivodship, the focus is primarily on integrat-

ing AI into traditional industries like manufacturing and energy, reflecting the region's historical emphasis on heavy industry. This creates opportunities for enhancing industrial efficiency and sustainability but also poses challenges related to the digital transformation of established sectors. In contrast, the Lesser Poland Voivodship adopts a broader approach, leveraging AI in life sciences, ICT, and sustainable energy, which aligns with its more diversified economic base. This strategy offers significant opportunities for innovation in emerging sectors, yet it also faces challenges in ensuring cohesive AI integration across these varied domains. Both regions, while advancing in AI adoption, must address region-specific issues such as workforce readiness and infrastructure development to fully capitalize on AI's potential in smart city management.

A human-centric approach significantly influences the adoption and effectiveness of AI in enhancing urban services in the Silesian and Lesser Poland Voivodships by prioritizing the needs and well-being of residents in the design and implementation of smart city initiatives (Q2). In traffic management, this approach ensures that AI-driven systems are not only efficient but also accessible and user-friendly, improving the daily commute experience and safety for all citizens. In healthcare, a human-centric focus enhances the relevance and accuracy of AI applications, such as diagnostic tools and personalized treatment plans, by considering patient needs and fostering trust in technology. For environmental sustainability, this approach ensures that AI technologies are deployed with a commitment to equitable resource management and community involvement, leading to more inclusive and effective environmental strategies. By centering AI initiatives on human values and ethical considerations, both Voivodships can achieve greater public acceptance, fostering more sustainable and livable urban environments.

The socio-technical dynamics involved in the deployment of AI in smart cities within the Silesian and Lesser Poland regions encompass the complex interplay between technological innovation and social structures, impacting inclusivity, transparency, and ethical considerations (Q3). These dynamics include the integration of AI technologies into existing urban infrastructures and the adaptation of societal behaviors and policies to support this integration. In these regions, ensuring inclusivity means addressing the digital divide by providing equal access to AI benefits across different demographics, which requires both technological infrastructure and community engagement. Transparency is influenced by how openly AI systems are implemented, with clear communication about data usage and decision-making processes being crucial to building public trust. Ethical considerations are shaped by the region's commitment to protecting privacy, preventing bias in AI systems, and ensuring that AI deployment aligns with broader societal values. In both Silesian and Lesser Poland, the successful navigation of these socio-technical dynamics is essential for creating smart cities that are not only technologically advanced but also socially equitable and ethically sound.

AI-driven smart city initiatives play a crucial role in advancing sustainable development goals in the Silesian and Lesser Poland Voivodships by optimizing key urban areas such as energy efficiency, waste management, and urban mobility (Q4). In energy efficiency, AI enables smart grids and predictive systems that balance energy demand and supply, reduce waste, and lower emissions, directly contributing to climate action goals. In waste management, AI-powered systems improve the sorting, recycling, and disposal processes, minimizing environmental impact and promoting a circular economy. Urban mobility benefits from AI through enhanced traffic management, reducing congestion and pollution and fostering the use of sustainable transport modes. These AI applications not only improve operational efficiency but also ensure that urban growth in these regions aligns with environmental sustainability and resource conservation objectives, thereby supporting broader sustainable development agendas.

The success of AI integration in smart city strategies within the Silesian and Lesser Poland Voivodships is determined by several key factors rooted in the regions' regional innovation policies (Q5). Firstly, the availability of robust digital infrastructure is critical, as it supports the deployment and scalability of AI technologies across various urban

services. Secondly, the alignment of AI initiatives with local industry strengths—such as manufacturing in Silesia and ICT in Lesser Poland—ensures that AI applications are relevant and beneficial to the region's economic landscape. Additionally, the effectiveness of public–private partnerships plays a significant role in facilitating collaboration between government, academia, and industry to drive innovation and address region-specific challenges. Workforce readiness is also crucial, as the regions need a skilled labor force capable of leveraging AI technologies effectively. Finally, the policies must prioritize inclusivity, transparency, and ethical considerations to ensure public trust and widespread adoption of AI-driven solutions. Together, these factors create a conducive environment for the successful integration of AI in smart city strategies, enabling sustainable and innovative urban development.

In the Silesian Voivodship, the paper examines how AI is integrated into traditional industries and urban infrastructure. For traffic management, it presents data on AI systems that facilitate real-time monitoring and adaptive control of traffic signals. These systems have led to tangible improvements in traffic flow, reduction in congestion, and enhanced air quality, thereby demonstrating AI's role in making urban transportation more efficient and environmentally friendly. Similarly, the paper delves into AI applications in healthcare within the region, showcasing advancements in diagnostic accuracy and personalized treatment. Specific case studies highlight how AI enhances patient care, improves early disease detection, and reduces the burden on healthcare services, thus providing concrete evidence of AI's transformative impact in medical fields.

In terms of energy efficiency, the paper explores how AI-driven systems optimize energy consumption and distribution. The analysis includes examples of smart grids and predictive analytics that balance supply and demand, reduce waste, and support the region's sustainability goals. These case studies illustrate AI's significant contributions to energy management and its alignment with broader environmental objectives. On the environmental management front, the paper provides evidence of AI's role in monitoring and managing natural resources, waste, and pollution. It details specific AI technologies used for water quality monitoring and waste classification, demonstrating how these systems contribute to maintaining urban sustainability and improving ecological balance.

Similarly, the Lesser Poland Voivodship is analyzed with a focus on its broader approach to AI applications. The paper presents case studies that show how AI is leveraged in life sciences, sustainable energy, and ICT. These examples underscore how AI contributes to regional competitiveness and innovation, aligning with the region's strategy to foster technological advancement and environmental sustainability. The empirical evidence and case studies presented in the paper are crucial for understanding the practical applications and benefits of AI across different sectors. By providing detailed insights into how AI is utilized in these regions, the paper effectively demonstrates the real-world impact of AI technologies on urban management, highlighting their contributions to efficiency, sustainability, and quality of life. This approach not only illustrates the immediate benefits of AI but also sets the foundation for future research and policy development aimed at optimizing AI integration in smart cities.

The main scientific value of the paper lies in its comprehensive exploration of how Artificial Intelligence (AI) can be effectively integrated into urban management to enhance sustainability, efficiency, and livability. This study contributes to the growing body of knowledge on smart city development by providing detailed case studies and empirical evidence from the Silesian and Lesser Poland Voivodships, illustrating the practical applications and benefits of AI in various urban sectors.

A significant scientific contribution of this paper is its interdisciplinary approach, combining insights from urban planning, environmental science, and technology studies. By analyzing AI's role in traffic management, energy efficiency, healthcare, and environmental management, the paper offers a holistic view of how AI technologies can address complex urban challenges. This integrated perspective is crucial for developing smart city strategies that are not only technologically advanced but also socially and environmentally sustain-

able. The paper's emphasis on a human-centric approach further enhances its scientific value. It underscores the importance of aligning technological innovations with the needs and values of urban residents, ensuring that AI-driven solutions are accessible, equitable, and beneficial for all. This focus on inclusivity and ethical considerations provides a critical counterbalance to purely technical perspectives, highlighting the role of social factors in the successful implementation of AI in smart cities. Also, the paper contributes valuable insights into the socio-technical dynamics of AI integration. By applying Socio-Technical Systems Theory (STST), the study elucidates the interdependencies between technology and social structures, emphasizing the need for user engagement, community involvement, and adaptive strategies. This theoretical framework helps to contextualize the empirical findings, offering a deeper understanding of the factors that influence the success and acceptance of AI technologies in urban environments.

A limitation of the paper is its focus on a limited geographic area, which may restrict the generalizability of its findings to other regions with different socio-economic, cultural, and infrastructural contexts. While the case studies from the Silesian and Lesser Poland Voivodships provide valuable insights, the specific conditions and challenges faced in these areas may not fully represent those in other urban environments globally. Additionally, the paper predominantly highlights the benefits of AI integration, potentially underemphasizing the challenges and risks, such as data privacy concerns, the digital divide, and the potential for algorithmic biases.

References

1. Skubis, I.; Wodarski, K. Humanoid robots in managerial positions—decision-making process and human oversight. *Sci. Pap. Silesian Univ. Technol.* **2023**, *189*, 573–596. [CrossRef]
2. *ISO 37122:2019*; Sustainable Cities and Communities—Indicators for Smart Cities. ISO International Standarisation Organisation: Geneva, Switzerland, 2019.
3. Available online: https://commission.europa.eu/eu-regional-and-urban-development/topics/cities-and-urban-development/city-initiatives/smart-cities_en (accessed on 10 April 2024).
4. Turoń, K. Complaints Analysis as an Opportunity to Counteract Social Transport Exclusion in Shared Mobility Systems. *Smart Cities* **2022**, *5*, 875–888. [CrossRef]
5. Stecuła, K.; Wolniak, R.; Grebski, W.W. AI-Driven Urban Energy Solutions—From Individuals to Society: A Review. *Energies* **2023**, *16*, 7988. [CrossRef]
6. Wolniak, R.; Jonek-Kowalska, I. The creative services sector in Polish cities. *J. Open Innov. Technol. Mark. Complex.* **2022**, *8*, 17. [CrossRef]
7. Ashokkumar, S.R.; Harihar, R.; Subhashini, R.; Naveen Prasaath, S. A Literature Survey on Artificial Intelligence-Based Smart City Automation Using LoRa and IOT for Street Lights and Air Quality Check. In Proceedings of the 2022 1st International Conference on Computer, Power and Communications (ICCPC 2022), Chennai, India, 14–16 December 2022; pp. 149–152.
8. Ray, J.K.; Sultana, R.; Bera, R.; Sil, S.; Alfred, Q.M. A Comprehensive Review on Artificial Intelligence (AI) and Robotic Process Automation (RPA) for the Development of Smart Cities. In *Confluence of Artificial Intelligence and Robotic Process Automation*; Springer: Singapore, 2023; pp. 289–311.
9. Kuguoglu, B.K.; van der Voort, H.; Janssen, M. The giant leap for smart cities: Scaling up smart city artificial intelligence of things (AIOT) initiatives. *Sustainability* **2021**, *13*, 12295. [CrossRef]
10. Schintler, L.A.; McNeely, C.L. Artificial intelligence, institutions, and resilience: Prospects and provocations for cities. *J. Urban Manag.* **2022**, *11*, 256–268. [CrossRef]

11. Vrabie, C. Artificial Intelligence Promises to Public Organizations and Smart Cities. In *PLAIS EuroSymposium on Digital Transformation*; Springer: Berlin/Heidelberg, Germany, 2022; pp. 3–14.

12. Harnal, S.; Sharma, G.; Malik, S.; Kaur, G.; Khurana, S.; Kaur, P.; Simaiya, S.; Bagga, D. Bibliometric mapping of trends, applications and challenges of artificial intelligence in smart cities. *EAI Endorsed Trans. Scalable Inf. Syst.* **2022**, *9*, e8. [CrossRef]

13. Seng, K.P.; Ang, L.-M.; Ngharamike, E.; Peter, E. Ridesharing and Crowdsourcing for Smart Cities: Technologies, Paradigms and Use Cases. *IEEE Access* **2023**, *11*, 18038–18081. [CrossRef]

14. Leali, F.; Pasquale, F. The Living Lab for Autonomous Driving as Applied Research of MaaS Models in the Smart City: The Case Study of MASA—Modena Automotive Smart Area. In Proceedings of the International Conference on Technological Imagination in the Green and Digital Transition, Rome, Italy, 30 June–2 July 2022; Springer: Berlin/Heidelberg, Germany, 2022; pp. 273–284.

15. Moumen, I.; Abouchabaka, J.; Rafalia, N. Enhancing urban mobility: Integration of IoT road traffic data and artificial intelligence in smart city environment. Indones. *J. Electr. Eng. Comput. Sci.* **2023**, *32*, 985–993. [CrossRef]

16. Abbas, Q.; Ahmad, G.; Alyas, T.; Alghamdi, T.; Alsaawy, Y.; Alzahrani, A. Revolutionizing Urban Mobility: IoT-Enhanced Autonomous Parking Solutions with Transfer Learning for Smart Cities. *Sensors* **2023**, *23*, 8753. [CrossRef]

17. Kubik, A. The Use of Artificial Intelligence in the Assessment of User Routes in Shared Mobility Systems in Smart Cities. *Smart Cities* **2023**, *6*, 1858–1878. [CrossRef]

18. Katal, N. AI-driven healthcare services and infrastructure in smart cities, Smart Cities: Blockchain, AI, and Advanced Computing. In *Smart Cities*; CRC Press: Boca Raton, FL, USA, 2024; pp. 150–170.

19. Rastogi, R.; Jain, R.; Mishra, P.; Shahjahan, M. Healthcare records maintenace in smart cities for healthcare 4.0: A approach with blockchain. In *Lightweight Digital Trust Architectures in the Internet of Medical Things (IoMT)*; IGI Global: Hershey, PA, USA, 2024; pp. 166–195.

20. Vashishth, T.K.; Sharma, V.; Sharma, K.K.; Chaudhary, S.; Panwar, R. IoMT in smart cities scaling challenges, smart healthcare applications, data integrity. In *Lightweight Digital Trust Architectures in the Internet of Medical Things (IoMT)*; IGI Global: Hershey, PA, USA, 2024; pp. 281–309.

21. Kaur, J. IoMT and the Urban Tapestry: Weaving healthcare into smart city frameworks. In *Lightweight Digital Trust Architectures in the Internet of Medical Things (IoMT)*; IGI Global: Hershey, PA, USA, 2024; pp. 265–280.

22. Renugadevi, R. Disease monitoring and management: Healthcare information systems (HIS) in smart cities. In *Analyzing Current Digital Healthcare Trends Using Social Networks*; IGI Global: Hershey, PA, USA, 2024; pp. 178–192.

23. Natarajan, N.R.; Veerasamy, V. Security and its implications on healthcare in an IoT-enabled smart city. In *Secure and Intelligent IoT-Enabled Smart Cities*; IGI Global: Hershey, PA, USA, 2024; pp. 296–307.

24. Kaur, J. Green healthcare in smart cities: Harnessing IoT for sustainable transformation of healthcare systems. In *Secure and Intelligent IoT-Enabled Smart Cities*; IGI Global: Hershey, PA, USA, 2024; pp. 334–354.

25. Kaur, J. Towards a sustainable Triad: Uniting energy management systems, smart cities, and green healthcare for a greener future. In *Emerging Materials, Technologies, and Solutions for Energy Harvesting*; IGI Global: Hershey, PA, USA, 2024; pp. 258–285.

26. Bokhari, S.A.A.; Seunghwan, M. How Do Institutional and Technological Innovations Influence the Smart City Governance? Focused on Stakeholder Satisfaction and Crime Rate. *Sustainability* **2024**, *16*, 4246. [CrossRef]

27. Rahman, A.-S.; Anubhove, M.S.T.; Zeyad, M.; Ahmed, S.M.M.; Walid, M.A.A. Study of City Crimes with Smart Solutions Integrating into Smart Cities, Internet of Things (IoT), and Cybersecurity Systems. In Proceedings of the 2nd International Conference on Advancements in Smart, Secure and Intelligent Computing, ASSIC, Bhubaneswar, India, 27–29 January 2024.

28. Minardi, R.; Villani, M.L.; De Nicola, A. Semantic Reasoning for Geolocalized Assessment of Crime Risk in Smart Cities. *Smart Cities* **2023**, *6*, 179–195. [CrossRef]

29. O'Malley, P.; Smith, G.J.D. 'Smart' crime prevention? Digitization and racialized crime control in a Smart City. *Theor. Criminol.* **2022**, *26*, 40–56. [CrossRef]

30. Isalova, M.; Shakhbanova, I.; Shabanova, M.; Sigal, A.; Babaeva, D. Application of public-private partnership in smart city projects implementation considering environmental management. *BIO Web Conf.* **2023**, *113*, 05033. [CrossRef]

31. Nandhini, B.; Kanagaraj, P.; Junead, J. Green Energy Management and Environmental Monitoring for Smart Cities. In Proceedings of the International Conference on Sustainable Communication Networks and Application, ICSCNA 2023, Theni, India, 15–17 November 2023; pp. 864–869.

32. Zang, H.; Chandru Vignesh, C.; Alfred Daniel, J. Influence of Social and Environmental Responsibility in Energy Efficiency Management for Smart City. *J. Interconnect. Netw.* **2023**, *22*, 2141002. [CrossRef]

33. Xia, X.; Wu, X.; BalaMurugan, S.; Marimuthu, K. Effect of environmental and social responsibility in energy-efficient management models for smart cities infrastructure. *Sustain. Energy Technol. Assess.* **2021**, *47*, 101525. [CrossRef]

34. Aïdi, N.; Fabry, N. Beyond the certification of smart tourism destination: Insights from the city of Medellín in Colombia. *Int. J. Tour. Cities* **2024**, *10*, 577–603. [CrossRef]

35. Prasad, D.; Singh, R.P.; Mahata, S.; Roy, R.; Khan, M.I. Green energy supply for sustainable tourism accommodation center in smart city. In *Promoting Multi-Sector Sustainability with Policy and Innovation*; IGI Global: Hershey, PA, USA, 2024; pp. 177–209.

36. Chang, K.-Y.; Chen, C.-D.; Ku, E.C.S. Enhancing smart tourism and smart city development: Evidence from Taoyuan smart aviation city in Taiwan. *Int. J. Tour. Cities* **2024**, *10*, 146–165. [CrossRef]

37. Ivars-Baidal, J.; Casado-Díaz, A.B.; Navarro-Ruiz, S.; Fuster-Uguet, M. Smart tourism city governance: Exploring the impact on stakeholder networks. *Int. J. Contemp. Hosp. Manag.* **2024**, *36*, 582–601. [CrossRef]

38. Liébana-Cabanillas, F.; Higueras-Castillo, E.; Coca-Stefaniak, J.A.; Molinillo, S. Smart or sustainable? Toward smart tourism cities that deliver at both levels. In *Handbook on Sustainable Urban Tourism*; Edward Elgar Publishing: Cheltenham, UK, 2024; pp. 159–177.

39. Wolniak, R.; Gajdzik, B.; Grwbski, M.; Danel, R.; Grebski, W.W. Business Models Used in Smart Cities—Theoretical Approach with Examples of Smart Cities. *Smart Cities* **2024**, *7*, 1626–1669. [CrossRef]

40. Sadeghian Broujeny, R.; Madani, K.; Chebira, A.; Amarger, V.; Hurtard, L. A Heating Controller Designing Based on Living Space Heating Dynamic's Model Approach in a Smart Building. *Energies* **2021**, *14*, 998. [CrossRef]

41. Goman, V.V.; Korolev, S.I. Smart thermostats in building automation systems and smart homes. *KnE Eng.* **2020**, *5*, 67–74. [CrossRef]

42. Huang, K.; Hallinan, K.P.; Lou, R.; Alanezi, A.; Alshatshati, S.; Sun, Q. Self-learning algorithm to predict indoor temperature and cooling demand from smart WiFi thermostat in a residential building. *Sustainability* **2020**, *12*, 7110. [CrossRef]

43. Cannavale, A.; Ayr, U.; Fiorito, F.; Martellotta, F. Smart electrochromic windows to enhance building energy efficiency and visual comfort. *Energies* **2020**, *13*, 1449. [CrossRef]

44. Nundy, S.; Mesloub, A.; Alsolami, B.M.; Ghosh, A. Electrically actuated visible and near-infrared regulating switchable smart window for energy positive building: A review. *J. Clean. Prod.* **2021**, *301*, 126854. [CrossRef]

45. Raza, A.; Baloch, M.H.; Ali, I.; Ali, W.; Hassan, M.; Karim, A. Artificial Intelligence and IoT-Based Autonomous Hybrid Electric Vehicle with Self-Charging Infrastructure. In Proceedings of the 2022 International Conference on Emerging Technologies in Electronics, Computing and Communication (ICETECC), Jamshoro, Pakistan, 7–9 December 2022; IEEE: Toulouse, France, 2022; pp. 1–6.

46. Zahedi, R.; Ardehali, M.M. Power management for storage mechanisms including battery, supercapacitor, and hydrogen of autonomous hybrid green power system utilizing multiple optimally-designed fuzzy logic controllers. *Energy* **2020**, *204*, 117935. [CrossRef]

47. Barron, L. Smart cities, connected cars and autonomous vehicles: Design fiction and visions of smarter future urban mobility. *Technoetic Arts* **2022**, *20*, 225–240. [CrossRef]

48. Yaqoob, I.; Khan, L.U.; Kazmi, S.M.A.; Guizani, N.; Hong, C.S. Autonomous Driving Cars in Smart Cities: Recent Advances, Requirements, and Challenges. *IEEE Netw.* **2020**, *34*, 174–181. [CrossRef]

49. Narkoziev, A.; Ibraeva, A.; Ayazbayeva, A.T.; Moldosanov, U. Digitalization of education in the context of personnel training for the maintenance of the Smart city infrastructure. *E3S Web Conf.* **2024**, *535*, 05004. [CrossRef]

50. Scala, D.; Aguilar Cuesta, Á.I.; Rodríguez-Domenech, M.Á.; Cañizares Ruiz, M.D.C. Bibliometric Study on the Conceptualisation of Smart City and Education. *Smart Cities* **2024**, *7*, 597–614. [CrossRef]

51. Barrera-Cámara, R.A.; Fuentes-Penna, A.; Bernabe-Loranca, M.B. Tools and technologies for smart education in sustainable smart cities. In *Management, Technology, and Economic Growth in Smart and Sustainable Cities*; IGI Global: Hershey, PA, USA, 2023; pp. 156–173.

52. Godwin, R.; Wisudha, A.; Wibowo, R.S.; Peranginangin, Y.A.; Desson, S. Developing smart people in smart cities through education: The role of personality. *E3S Web Conf.* **2023**, *426*, 01059. [CrossRef]

53. Sha, K.; Taeihagh, A.; De Jong, M. Governing disruptive technologies for inclusive development in cities: A systematic literature review. *Technol. Forecast. Soc. Chang.* **2024**, *203*, 123382. [CrossRef]

54. 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]

55. Kitchin, R. The real-time city? Big data and smart urbanism. *GeoJournal* **2014**, *79*, 1–14. [CrossRef]

56. Bibri, S.E.; Krogstie, J. Smart sustainable cities of the future: An extensive interdisciplinary literature review. *Sustain. Cities Soc.* **2017**, *31*, 183–212. [CrossRef]

57. Filho, W.L.; Vidal, D.G.; Chen, C.; Petrova, M.; Dinis, M.A.P.; Yang, P.; Rogers, S.; Álvarez-Castañón, L.; Djekic, I.; Sharifi, A.; et al. An assessment of requirements in investments new technologies and infrastructures to achieve the SDGs. *Environ. Sci. Eur.* **2022**, *34*, 58. [CrossRef] [PubMed]

58. Kabus, J.; Dziadkiewicz, M. Residents' Attitudes and Social Innovation Management in the Example of a Municipal Property Manager. *Energies* **2022**, *15*, 5812. [CrossRef]

59. Allam, Z.; Jones, D.S. Future (post-COVID) digital smart and sustainable cities in the wake of 6G: Digital twins immersive realities and new urban economies. *Land Use Policy* **2021**, *101*, 105201. [CrossRef]

60. Shorfuzzaman, M.; Hossain, M.S.; Alhamid, M.F. Towards the sustainable development of smart cities through mass video surveillance: A response to the COVID-19 pandemic. *Sustain. Cities Soc.* **2021**, *64*, 102582. [CrossRef]

61. Herrera-Quintero, L.F.; Chavarriaga, J.; Banse, K.; Bermudez, D.; Proeller, G. Disruptive technologies in intelligent transportation systems. In Proceedings of the 2019 2nd Latin American Conference on Intelligent Transportation Systems (ITS LATAM), Bogota, Colombia, 19–20 March 2019; IEEE: Piscataway, NJ, USA, 2019; pp. 1–6.

62. Radu, L.D. Disruptive technologies in smart cities: A survey on current trends and challenges. *Smart Cities* **2020**, *3*, 1022–1038. [CrossRef]

63. Taeihagh, A.; Ramesh, M.; Howlett, M. Assessing the regulatory challenges of emerging disruptive technologies. *Regul. Gov.* **2021**, *15*, 1009–1019. [CrossRef]

64. Choi, T.M.; Kumar, S.; Yue, X.; Chan, H.L. Disruptive technologies and operations management in the industry 4.0 era and beyond. *Prod. Oper. Manag.* **2022**, *31*, 9–31. [CrossRef]

65. Ingwersen, P.; Serrano-López, A.E. Smart city research 1990–2016. *Scientometrics* **2018**, *117*, 1205–1236. [CrossRef]

66. Herath, H.M.K.K.M.B.; Mittal, M. Adoption of artificial intelligence in smart cities: A comprehensive review. *Int. J. Inf. Manag. Data Insights* **2022**, *2*, 100076. [CrossRef]

67. Wojtaszek, H.; Miciuła, I.; Gac, M.; Kabus, D.; Balcerzyk, R.; Będźmirowski, J.; Kowalczyk, A. Social and Environmental Responsibility Manager on the Example of Companies from Poland and Germany. *Sustainability* **2023**, *15*, 14359. [CrossRef]

68. Golubchikov, O.; Thornbush, M. Artificial Intelligence and Robotics in Smart City Strategies and Planned Smart Development. *Smart Cities* **2020**, *3*, 1133–1144. [CrossRef]

69. Srebalová, M.; Peráček, T. Effective Public Administration as a Tool for Building Smart Cities: The Experience of the Slovak Republic. *Laws* **2022**, *11*, 67. [CrossRef]

70. Mutambik, I. The Use of AI-Driven Automation to Enhance Student Learning Experiences in the KSA: An Alternative Pathway to Sustainable Education. *Sustainability* **2024**, *16*, 5970. [CrossRef]

71. Wolniak, R. European Union Smart Mobility—Aspects Connected with Bike Road System's Extension and Dis-semination. *Smart Cities* **2023**, *6*, 1009–1042. [CrossRef]

72. Wolniak, R. Analysis of the Bicycle Roads System as an Element of a Smart Mobility on the Example of Poland Provinces. *Smart Cities* **2023**, *6*, 368–391. [CrossRef]

73. Turoń, K.; Toth, J. Innovations in Shared Mobility—Review of Scientific Works. *Smart Cities* **2023**, *6*, 1545–1559. [CrossRef]

74. Ahmad, K.; Maabreh, M.; Ghaly, M.; Khan, K.; Qadir, J.; Al-Fuqaha, A. Developing future human-centered smart cities: Critical analysis of smart city security, Data management, and Ethical challenges. *Comput. Sci. Rev.* **2022**, *43*, 100452. [CrossRef]

75. Hollands, R.G. Will the real smart city please stand up? *City* **2008**, *12*, 303–320. [CrossRef]

76. Skubis, I.; Akahome, J. Exploring transformational customer experience in digital banking: An exploratory study. *Organ. Manag. Sci. Q.* **2022**, *3*, 97–112.

77. Wołk, A.; Skowrońska, H.; Skubis, I. Multilingual Chatbot for E-Commerce: Data Generation and Machine Translation. *PACIS 2021 Proc.* **2021**, *232*, 1–14.

78. Verhoef, P.C.; Kannan, P.K.; Inman, J.J. From Multi-Channel Retailing to Omni-Channel Retailing: Introduction to the Special Issue on Multi-Channel Retailing. *J. Retail.* **2015**, *91*, 174–181. [CrossRef]

79. Skubis, I. Językoznawstwo jako bezpieczna dyscyplina dla badań nad sztuczną inteligencją. In *Prawo Sztucznej Inteligencji i Nowych Technologii*; Fischer, B., Pązik, A., Świerczyński, M., Eds.; Wolters Kluwer: Warszawa, Poland, 2021; pp. 169–181.

80. Kitchin, R. Making sense of smart cities: Addressing present shortcomings. *Camb. J. Reg. Econ. Soc.* **2015**, *8*, 131–142. [CrossRef]

81. 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 2012 45th Hawaii International Conference on System Science (HICSS), Maui, HI, USA, 4–7 January 2012; pp. 2289–2297.

82. Wang, B.; Dabbaghjamanesh, M.; Kavousi-Fard, A.; Yue, Y. AI-enhanced multi-stage learning-to-learning approach for secure smart cities load management in IoT networks. *Ad Hoc Netw.* **2024**, *164*, 103628.

83. Issaoui, I.; Selmi, A. Weighted Soft Discernibility Matrix with Deep Learning Assisted Face Mask Detection for Smart City Environment. *Int. J. Neutrosophic Sci.* **2025**, *25*, 179–189. [CrossRef]

84. Thuzar, M. Participation in the smart city: Civic engagement and inclusive urban development. *Urban Dev.* **2015**, *22*, 1–18.

85. Ahvenniemi, H.; Huovila, A.; Pinto-Seppä, I.; Airaksinen, M. What are the differences between sustainable and smart cities? *Cities* **2017**, *60*, 234–245. [CrossRef]

86. Moumen, N.; Radoine, H.; Nahiduzzaman, K.M.; Jarar Oulidi, H. Contextualizing the Smart City in Africa: Balancing Human-Centered and Techno-Centric Perspectives for Smart Urban Performance. *Smart Cities* **2024**, *7*, 712–734. [CrossRef]

87. Shin, J.E.; Joe, M.; Kim, E.; Lee, J.; Lee, S.-W. Unboxing the blackbox of human-centric and inclusive smart city initiatives: A theory based evaluation framework. *Asian J. Technol. Innov.* **2024**, 1–24. [CrossRef]

88. Mangarah, A.S.; Ryerson, M. 7 Principles Al Madinah Has Followed to Design Human-Centric Smart Cities. In *Advances in Science Technology and Innovation*; Springer: Cham, Switzerland, 2024; pp. 117–134.

89. Hu, W.; Wang, S.; Zhai, W. Human-centric vs. technology-centric approaches in a top-down smart city development regime: Evidence from 341 Chinese cities. *Cities* **2023**, *137*, 104271. [CrossRef]

90. Jonek-Kowalska, I. The Exclusiveness of Smart Cities—Myth or Reality? Comparative Analysis of Selected Economic and Demographic Conditions of Polish Cities. *Smart Cities* **2023**, *6*, 2722–2741. [CrossRef]

91. Jonek-Kowalska, I. Assessing the Effectiveness of Air Quality Improvements in Polish Cities Aspiring to Be Sustainably Smart. *Smart Cities* **2023**, *6*, 510–530. [CrossRef]

92. Wolniak, R.; Stecuła, K. Artificial Intelligence in Smart Cities—Applications, Barriers and Future Directions: A Review. *Smart Cities* **2024**, *7*, 1346–1389. [CrossRef]

93. Jonek-Kowalska, I.; Wolniak, R. *Towards Sustainability and a Better Quality of Life?* Routledge: London, UK, 2023.

94. Monzon, A. Smart cities concept and challenges: Bases for the assessment of smart city projects. In Proceedings of the 2015 International Conference on Smart Cities and Green ICT Systems (SMARTGREENS), Lisbon, Portugal, 20–22 May 2015.

95. Suryawan, I.W.K.; Mulyana, R.; Yenis Septiariva, I.; Sari, M.M.; Ulhasanah, N. Smart urbanism, citizen-centric approaches and integrated environmental services in transit-oriented development in Jakarta, Indonesia. *Res. Glob.* **2024**, *8*, 100181. [CrossRef]

96. Skubis, I.; Akahome, J.; Bijańska, J. Green innovations in healthcare sector in Nigeria. *Sci. Pap. Silesian Univ. Technol. Organ. Manag. Ser.* **2023**, *176*, 577–596. [CrossRef]
97. Skubis, I.; Akahome, J.; Bijańska, J. The brain drain syndrome and the role of responsible leadership in health care service organisation in Nigeria. *Sci. Pap. Silesian Univ. Technol. Organ. Manag. Ser.* **2023**, *176*, 599–615. [CrossRef]
98. Liao, Z.; Zhang, M. The Influence of Responsible Leadership on Environmental Innovation and Environmental Performance: The Moderating Role of Managerial Discretion. *Corp. Soc. Responsib. Environ. Manag.* **2020**, *27*, 2016–2027. [CrossRef]
99. Cardullo, P.; Kitchin, R. Smart urbanism and smart citizenship: The neoliberal logic of 'citizen-focused' smart cities in Europe. *Environ. Plan. C Politics Space* **2019**, *37*, 813–830. [CrossRef]
100. Lytras, M.D.; Visvizi, A. Who uses smart city services and what to make of it: Toward interdisciplinary smart cities research. *Sustainability* **2018**, *10*, 1998. [CrossRef]
101. Hollands, R.G. Critical interventions into the corporate smart city. *Camb. J. Reg. Econ. Soc.* **2015**, *8*, 61–77. [CrossRef]
102. Caragliu, A.; Del Bo, C. Smart innovative cities: The impact of Smart City policies on urban innovation. *Technol. Forecast. Soc. Chang.* **2019**, *142*, 373–383. [CrossRef]
103. Alajlan, N.N.; Ibrahim, D.M. Deep Smart Cities: A Review of Smart Cities Applications-Based an Inference of Deep Learning Upon IoT Devices. *J. Adv. Res. Appl. Sci. Eng. Technol.* **2025**, *47*, 94–120. [CrossRef]
104. Owusu, A. Knowledge Management Systems Implementation Effects on University Students' Academic Performance: The Socio-Technical Theory Perspective, Education and Information Technologies. *Educ. Inf. Technol.* **2024**, *29*, 4417–4442. [CrossRef]
105. Partanen, T.; Seppänen-Järvelä, R.; Hiekkala, S.; Lindh, J. Telerehabilitation in the Finnish Outpatient Rehabilitation Setting from the Perspective of the Socio-Technical Systems Theory. *Int. J. Environ. Res. Public Health* **2024**, *20*, 6519. [CrossRef]
106. Zhang, X.; Nutakor, F.; Minlah, M.K.; Li, J. Can Digital Transformation Drive Green Transformation in Manufacturing Companies?—Based on Socio-Technical Systems Theory Perspective. *Sustainability* **2023**, *15*, 2840. [CrossRef]
107. Yao, H.; Xu, P.; Wang, Y.; Chen, R. Exploring the low-carbon transition pathway of China's construction industry under carbon-neutral target: A socio-technical system transition theory perspective. *J. Environ. Manag.* **2023**, *327*, 116879. [CrossRef]
108. Kolukuluri, M.; Singh, J.B. A qualitative study on project failure in agile teams using socio-technical systems theory. In Proceedings of the Annual Hawaii International Conference on System Sciences, Maui, HI, USA, 3–6 January 2023; pp. 6528–6537.
109. Münch, C.; Marx, E.; Benz, L.; Hartmann, E.; Matzner, M. Capabilities of digital servitization: Evidence from the socio-technical systems theory. *Technol. Forecast. Soc. Chang.* **2022**, *176*, 121361. [CrossRef]
110. Holdsworth, M.; Zaghloul, F. The Impact of AI in the UK Healthcare Industry: A Socio-Technical System Theory Perspective. *CEUR Workshop Proc.* **2022**, *3239*, 52–63.
111. Sony, M.; Naik, S. Industry 4.0 integration with socio-technical systems theory: A systematic review and proposed theoretical model. *Technol. Soc.* **2020**, *61*, 101248. [CrossRef]
112. Zulkifli, N.S.; Roslan, S.N.A. The Effect of Technology Acceptance Model (TAM) Challenges in Building Information Modelling (BIM) Implementation in Relation to Malaysian Government Mandate. *J. Adv. Res. Appl. Sci. Eng. Technol.* **2024**, *40*, 140–151. [CrossRef]
113. Wandira, R.; Fauzi, A.; Nurahim, F. Analysis of Factors Influencing Behavioral Intention to Use Cloud-Based Academic Information System Using Extended Technology Acceptance Model (TAM) and Expectation-Confirmation Model (ECM). *J. Inf. Syst. Eng. Bus. Intell.* **2024**, *10*, 179–190. [CrossRef]
114. Nayak, A.; Satpathy, I. Bioelectronics in waste treatment systems: A Technology Acceptance Model (TAM) Approach. In *Revolutionizing Automated Waste Treatment Systems: IoT and Bioelectronics*; IGI Global: Hershey, PA, USA, 2024; pp. 221–236.
115. Paiman, N.; Fauzi, M.A. Exploring determinants of social media addiction in higher education through the integrated lenses of technology acceptance model (TAM) and usage habit. *J. Appl. Res. High. Educ.* **2024**, *16*, 776–803. [CrossRef]
116. Sasidharan, A.; Venkatakrishnan, S. Intension to Use Mobile Banking: An Integration of Theory of Planned Behaviour (TPB) and Technology Acceptance Model (TAM). *KSII Trans. Internet Inf. Syst.* **2024**, *18*, 1059–1074.
117. Prabowo, N.A.; Che Hanapi, A.N.C.P.; Ahmad, I. Investigating Technology Acceptance Model (TAM) for E-Da'wah: A Systematic Literature Review. *E3S Web Conf.* **2024**, *500*, 01012. [CrossRef]