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Artificial Intelligence and Robotics in Smart City Strategies: Automation, Governance, and Ethical Challenges

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Abstract

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Digital transformation through artificial intelligence (AI) and robotics is one of the key pillars in the smart city strategy. This development is influenced by the Industrial Revolution 4.0 which emphasizes the integration of cyber-physical systems, the Internet of Things, and big data to support urban governance and smart mobility. The study aims to analyze the application of AI and robotics in smart city strategies by highlighting five main categories: automation, decision-making, education, smart infrastructure, and smart mobility. The research method was carried out through a literature study by examining smart city strategies from various countries that are available online in the form of official documents. The results show that major cities have adopted AI for government transparency, energy efficiency, and public services. However, serious challenges arise related to data privacy, technological ethics, and socio-economic impacts due to work automation. This study emphasizes the need for an integrated socio-technical approach in realizing a sustainable and equitable smart city.

1. Introduction

The development of digital technology in the last two decades has changed the way cities are designed, managed, and experienced by their citizens. The concept of smart city emerged as a response to rapid urbanization, environmental pressures, and demands for the efficiency of public services. In this context, artificial intelligence (AI) and robotics play a central role as drivers of digital transformation. This technological integration is supported by the Industrial Revolution 4.0, which emphasizes the close relationship between cyber-physical systems, the Internet of Things (IoT), and big data, in order to realize smarter and more responsive urban governance.[1]

Smart cities are not only understood as spaces connected through digital infrastructure, but also as socio-technical ecosystems where technology is used to improve quality of life, reduce emissions, and improve governance transparency. AI and robotics function in multiple dimensions, from public service automation, data-driven decision-making, to intelligent mobility. Within this framework, five categories of adoption stand out: automation, decision-making, education, smart infrastructure, and smart mobility. These five categories illustrate the broad scope in which AI plays an enabler, not just a tool, in smart city building.[2]

Case studies show that major cities have adopted AI and robotics in their strategies. For example, Smart City 2030 plan integrates sensors, big data, and

[1] Mihai Andronie, George Lăzăroiu, Mariana Iatagan, Iulian Hurloiu, and Irina Dijmărescu. "Sustainable cyber-physical production systems in big data-driven smart urban economy: a systematic literature review." *Sustainability* 13, no. 2 (2021): 751.

[2] Ana Iolanda Voda and Laura-Diana Radu. "How can artificial intelligence respond to smart cities challenges?." In *Smart cities: Issues and challenges*, Elsevier, (2019): 199-216.

automated devices to support government transparency and infrastructure monitoring. The system allows for efficient management of energy, transportation, and public services while providing a mechanism for retraining the workforce to deal with job losses due to automation.[3] Meanwhile, in Portugal implementing an AI-sensor-based smart street lighting system to support energy efficiency, as part of a national strategy in the face of the Industrial Revolution 4.0. This example shows that the adoption of smart city technology can operate at various scales, from large metropolitan cities to medium-sized cities.

While technology brings opportunities, there are a number of serious challenges that need to be addressed. First, the issue of data privacy and security becomes increasingly complex when sensors, cameras, and AI algorithms enter the realm of citizens' personal lives. This issue raises questions about who owns and controls data, as well as how it is used in public decision-making. Second, there is a risk of the technocratization of cities, where decision-making is too dependent on algorithms, thereby reducing public participation in democratic processes. Third, the socio-economic impact of automation can exacerbate inequality, especially for low-skilled communities who are vulnerable to being replaced by machines.[4]

Ethical discourse is becoming increasingly important in the context of smart cities. Concepts such as responsible urban robotics emphasize the need for ethical

[3] Sita Rani, Ram Krishn Mishra, Mohammed Usman, Aman Kataria, Pramod Kumar, Pankaj Bhambri, and Amit Kumar Mishra. "Amalgamation of advanced technologies for sustainable development of smart city environment: A review." *IEEE Access* 9 (2021): 150060-150087.

[4] Sarah Rotz, Evan Gravely, Ian Mosby, Emily Duncan, Elizabeth Finnis, Mervyn Horgan, Joseph LeBlanc et al. "Automated pastures and the digital divide: How agricultural technologies are shaping labour and rural communities." *Journal of Rural Studies* 68 (2019): 112-122.

principles in the design, development, and application of AI technology. This principle includes the prevention of potential losses, the improvement of people's welfare, and respect for human rights. Thus, technology is not only seen as a tool for efficiency, but also as an instrument that should be directed to the broader social benefit.[5]

Taking into account these various opportunities and challenges, this study seeks to analyze smart city strategies in integrating AI and robotics. The focus is on how these technologies are being used to improve automation, decision-making, education, infrastructure, and mobility, while also understanding the social, economic, and ethical implications that arise. This study is expected to contribute to understanding the dynamics of sustainable smart city development, as well as emphasizing the importance of an integrated socio-technical approach that balances innovation with human values.

2. Literature Review

Research on the application of Artificial Intelligence (AI) and robotics in smart city strategies has grown in recent years, with a focus on technological opportunities as well as the accompanying social challenges. The literature shows that AI and robotics are not only playing a role as technical tools, but rather as key elements in changing the paradigm of urban governance. Golubchikov and

[5] Dirk Helbing, Farzam Fanitabasi, Fosca Giannotti, Regula Hänggli, Carina I. Hausladen, Jeroen van den Hoven, Sachit Mahajan, Dino Pedreschi, and Evangelos Pournaras. "Ethics of smart cities: Towards value-sensitive design and co-evolving city life." *Sustainability* 13, no. 20 (2021): 11162.

Thornbush[6] affirm that AI and robotic systems are important foundations for smart city development because they are able to improve automation, transparency, and data-driven decision-making. Other studies broaden the perspective by emphasizing the challenges that arise from the application of this technology. Cugurullo[7] identifies a shift from automation to autonomy in urban systems, where AI has the potential to make independent decisions that can influence social dynamics and democracy. This shift brings efficiency benefits but also raises questions about algorithmic accountability and its impact on citizen participation in urban governance.

On the other hand, ethical and sustainability issues are an important focus in the current literature. Chang[8] emphasized that smart cities need an ethical and legal framework that is able to balance technological innovation with the protection of individual rights and the interests of the wider community. This ethical approach includes the need for ethics-by-design in software development, data privacy settings, and community involvement in the planning process. Thus, a literature review shows that while AI and robotics offer great potential in improving the efficiency and sustainability of smart cities, the research also highlights the importance of regulation, ethics, and public participation as supporting aspects that determine the successful implementation of these technologies.

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[6] Oleg Golubchikov and Mary Thornbush. "Artificial intelligence and robotics in smart city strategies and planned smart development." *Smart Cities* 3, no. 4 (2020): 1-12.

[7] Federico Cugurullo. "Urban artificial intelligence: From automation to autonomy in the smart city." *Frontiers in Sustainable Cities* 2 (2020): 38.

[8] Victor Chang. "An ethical framework for big data and smart cities." *Technological Forecasting and Social Change* 165 (2021): 120559.

3. Method

The research method used in this study is a library research that focuses on smart city strategies which are available online in the form of official documents and academic publications. The sources analyzed include policy reports, smart city strategies in PDF format published by the government, as well as scientific articles discussing the implementation of artificial intelligence (AI) and robotics in urban contexts. Using this approach, the research seeks to examine the extent to which AI and robotics technologies are integrated into smart city planning and management, as well as how emerging narratives and practices describe the direction of urban development going forward.

The data collection process is carried out through searching academic literature on online databases, including Google Scholar, as well as through the city government's website and the official smart city portal that publishes strategies and related documents. The selected articles and documents were limited to the last five-year period, to ensure that the data obtained was relevant to the latest developments in the field of urban technology. From the results of this search, a number of publications were obtained that discussed smart city strategies in various parts of the world, so that they can provide a comparative picture of the variations in the application of AI and robotics in urban contexts. The analysis was carried out using a qualitative approach, where the content of the document was examined to identify key themes, patterns of technology application, and related socio-economic and ethical implications.

This analysis process emphasizes five main categories that have previously been identified in the literature, namely automation, decision-making, education, smart infrastructure, and smart mobility. These categories are used as a conceptual framework to compare different smart city strategies and assess the consistency and differences between cases. In addition, a socio-technical approach is used to understand the relationship between technological dimensions and social aspects. This is important because the smart city strategy is not only oriented towards the application of technology, but also on how it interacts with social structures, governance, and community welfare. Thus, this literature study method not only collects descriptive information, but also performs a critical interpretation of how smart city strategies frame the role of AI and robotics in sustainable development.

4. Results

4.1. Automation and Efficiency of Public Services

One of the key findings of the smart city strategy analysis is the central role of automation in improving the efficiency of public services. Automation powered by artificial intelligence (AI) and robotics enables cities to manage resources more efficiently, speed up administrative services, and improve the quality of life of citizens. Golubchikov and Thornbush[9] show that automation has become one of the key categories in smart city strategies, where robotic systems are used to replace routine work while supporting more accurate decision-making based on big data. A

[9] Oleg Golubchikov and Mary Thornbush. "Artificial intelligence and robotics in smart city strategies and planned smart development." *Smart Cities* 3, no. 4 (2020): 1-12.

concrete example can be seen in the implementation of a smart lighting system where AI-based sensors are used to automatically adjust the intensity of street light, thereby reducing energy consumption and operational costs. This innovation represents how automation works not only in the administrative space, but also in aspects of everyday urban infrastructure.

Rani et al.[10] said that the trend towards urban autonomy through AI has made cities more adaptive in responding to the needs of residents and environmental conditions in real-time. In addition, the application of AI in public service automation is also seen in the transportation and mobility sectors. Sensor-based transportation systems enable traffic optimization, reduce congestion, and reduce carbon emissions. Voda and Radu[11] emphasized that the integration of AI in intelligent transportation is an important milestone in building sustainable cities, as this technology is able to dynamically manage the flow of vehicles based on actual data. Thus, automation is not only related to energy efficiency, but also has a direct impact on environmental sustainability and people's comfort.

However, the adoption of automation in smart cities also poses a number of challenges. One of them is the potential replacement of human labor by machines, especially in the highly automated public service sector. Nedjah et al.[12] warn that while automation provides efficiency gains, it also has the potential to increase social

[10] Sita Rani, Ram Krishn Mishra, Mohammed Usman, Aman Kataria, Pramod Kumar, Pankaj Bhambri, and Amit Kumar Mishra. "Amalgamation of advanced technologies for sustainable development of smart city environment: A review." *IEEE Access* 9 (2021): 150060-150087.

[11] Ana Iolanda Voda and Laura-Diana Radu. "How can artificial intelligence respond to smart cities challenges?." In *Smart cities: Issues and challenges*, Elsevier, (2019): 199-216.

[12] Nadia Nedjah, Ahmed A. Abd El-Latif, Brij B. Gupta, and Luiza M. Mourelle, eds. *Robotics and AI for Cybersecurity and Critical Infrastructure in Smart Cities*. Vol. 1030. Springer Nature, (2022).

inequality if it is not balanced with reskilling policies of the workforce. In other words, while smart cities promise faster, more efficient, and cheaper public services, their long-term success depends on how social policies can adapt to technology-induced structural changes. This sub-chapter confirms that automation in smart city strategies is an important instrument in improving the efficiency of public services and environmental sustainability. However, the application of this technology must be accompanied by inclusive policies so as not to create new social gaps in urban communities.

4.2. Decision-Making and Urban Governance

The integration of artificial intelligence (AI) and robotics in smart cities is not only limited to automation aspects, but also plays a significant role in supporting decision-making and more transparent and responsive city governance. Andronie et al.[13] emphasize that modern smart city strategies place AI as a basis for improving the quality of city administrative decisions. Through big data analysis, AI is able to present accurate information, detect anomalies, and provide prediction-based recommendations that can reduce managerial errors. The city of Moscow is one prominent example, with its Smart City 2030 initiative using AI systems and sensors to support administrative decision-making. The system allows for automatic monitoring of energy, water, transportation, and environmental quality, so that decisions can be made quickly and based on actual data.

[13] Mihai Andronie, George Lăzăroiu, Mariana Iatagan, Iulian Hurloiu, and Irina Dijmărescu. "Sustainable cyber-physical production systems in big data-driven smart urban economy: a systematic literature review." *Sustainability* 13, no. 2 (2021): 751.

According to Helbing et al.[14] the implementation of AI-based governance like this has the potential to increase government transparency while building public trust in city institutions. However, the literature also points to the risks that come with relying on AI in governance processes. Cugurullo[15] warns that increasing the autonomy of AI systems can encourage "urban technocratization," where algorithms hold more control than human participation. This has the potential to reduce the quality of local democracy, because public decisions are more determined by predictive models and not the results of citizens' deliberations. The risk of algorithmic bias is also an important concern, as the data used in AI models often reflect existing social inequalities.

In addition, the study of Chamola et al.[16] highlights the need for a clear regulatory model to govern the use of AI in urban governance, particularly in times of crisis such as the pandemic. According to them, AI can strengthen the resilience of cities through the management of health services, logistics, and mobility. However, without proper regulation, the use of such technologies has the potential to violate individual privacy and raise serious ethical issues. Thus, the results of the analysis show that AI has a crucial role in improving the quality of decision-making and urban governance. However, in order for these benefits to be realized optimally,

[14] Dirk Helbing, Farzam Fanitabasi, Fosca Giannotti, Regula Hänggli, Carina I. Hausladen, Jeroen van den Hoven, Sachit Mahajan, Dino Pedreschi, and Evangelos Pournaras. "Ethics of smart cities: Towards value-sensitive design and co-evolving city life." *Sustainability* 13, no. 20 (2021): 11162.

[15] Federico Cugurullo. "Urban artificial intelligence: From automation to autonomy in the smart city." *Frontiers in Sustainable Cities* 2 (2020): 38.

[16] Vinay Chamola, Vikas Hassija, Vatsal Gupta, and Mohsen Guizani. "A comprehensive review of the COVID-19 pandemic and the role of IoT, drones, AI, blockchain, and 5G in managing its impact." *Ieee access* 8 (2020): 90225-90265.

clear regulatory policies, citizen participation mechanisms, and serious attention to ethical and privacy issues are needed. The integration of AI in smart city governance can only succeed if it is able to balance technological efficiency with the values of democracy and social justice.

4.3. Education, Smart Infrastructure, and Mobility

In addition to automation and governance, the application of artificial intelligence (AI) and robotics in smart city strategies also extends to the education, infrastructure, and mobility sectors. These three aspects are interrelated in supporting sustainable development while improving the quality of life of city residents. According to Voda and Radu[17], AI in the context of smart city education functions as a means of adaptive learning and supports human-machine interaction. Technologies such as social robots and digital tutors are used to enrich learning experiences, facilitate lifelong learning, and prepare people for job market changes due to automation.

In the infrastructure dimension, the development of AI and IoT presents the concept of smart infrastructure that is able to operate autonomously through sensors, real-time data, and predictive algorithms. Esenogho et al.[18] show that the integration of AI and IoT allows for more efficient energy, water, and transportation management, with systems that automatically adjust operations as needed. This

[17] Ana Iolanda Voda and Laura-Diana Radu. "How can artificial intelligence respond to smart cities challenges?." In *Smart cities: Issues and challenges*, Elsevier, (2019): 199-216.

[18] Ebenezer Esenogho, Karim Djouani, and Anish M. Kurien. "Integrating artificial intelligence Internet of Things and 5G for next-generation smartgrid: A survey of trends challenges and prospect." *Ieee Access* 10 (2022): 4794-4831.

reflects a shift towards an adaptive city, where infrastructure is not only passive but capable of "thinking" and responding to urban dynamics. Intelligent mobility is another dimension that is heavily influenced by AI. Autonomous transportation systems, prediction-based traffic management, and the use of connected electric vehicles are important elements in reducing congestion and carbon emissions. Rotz et al.[19] emphasize that AI technology not only improves mobility efficiency, but also contributes to transportation safety by detecting potential hazards quickly. Thus, the integration of smart mobility is one of the keys in achieving the sustainability goals of smart cities.

However, the application of technology in these three sectors also poses an ethical dilemma. Vodă and Radu[20] highlight that the use of AI in education and mobility raises privacy issues related to user data, while in infrastructure there are concerns about vulnerability to cyberattacks. Therefore, while these innovations present great opportunities, regulations and oversight mechanisms are still needed to maintain a balance between technological innovation and the protection of citizens' rights. The results of the study confirm that education, smart infrastructure, and mobility are the three important pillars in an AI-based smart city strategy. All three show how technology not only improves technical efficiency, but also shapes the socio-economic future of cities. The remaining challenge is to ensure that technology adoption goes hand in hand with regulations, ethics, and citizen

[19] Sarah Rotz, Evan Gravely, Ian Mosby, Emily Duncan, Elizabeth Finnis, Mervyn Horgan, Joseph LeBlanc et al. "Automated pastures and the digital divide: How agricultural technologies are shaping labour and rural communities." *Journal of Rural Studies* 68 (2019): 112-122.

[20] Ana Iolanda Vodă and Laura-Diana Radu. "Artificial intelligence and the future of smart cities." *BRAIN. Broad Research in Artificial Intelligence and Neuroscience* 9, no. 2 (2018): 110-127.

participation, so that the benefits can be enjoyed in an inclusive and sustainable manner.

5. Discussion

The results of this study show that artificial intelligence (AI) and robotics have become fundamental components of smart city strategies, with the scope of applications in automation, governance, education, infrastructure, and mobility. The findings are consistent with the views of Golubchikov and Thornbush[21] who emphasize that AI and robotics are not only technological complements, but foundations for future city development. However, its widespread adoption also raises important questions about the balance between technological efficiency and social values. In terms of opportunities, AI has been proven to be able to improve energy efficiency, government transparency, and convenience of public services. Several countries are real examples of how sensors and predictive systems can optimize infrastructure management. In addition, the integration of AI in education and mobility shows positive prospects in preparing society for technological disruption. This reinforces the argument that AI can be a catalyst for the sustainability of smart cities, especially when geared towards supporting environmental and social goals.

However, there are a number of challenges that cannot be ignored. First, the risk of replacing human jobs by machines raises concerns about rising social

[21] Oleg Golubchikov and Mary Thornbush. "Artificial intelligence and robotics in smart city strategies and planned smart development." *Smart Cities* 3, no. 4 (2020): 1-12.

inequality. This issue is reinforced by Nedjah et al.[22] who state that without a reskilling policy, automation can exacerbate the socio-economic gap. Second, city governance that relies too much on algorithms has the potential to create bias and reduce citizen participation. As stated by Cugurullo[23], the phenomenon of "urban technocratization" can weaken the democratic process if algorithms replace the space for public deliberation. Third, ethical and privacy aspects are crucial dimensions in the application of smart city technology. Data collected through sensors, cameras, and digital platforms often includes citizens' personal information, which if misused can threaten individual freedom.

Chang[24] emphasizes the need for ethical and legal frameworks to ensure that smart city technology respects individual rights while serving the collective interest. Thus, the development of smart cities requires not only technical innovation, but also a strict and inclusive regulatory system. This discussion emphasized that the success of smart cities is not only determined by their technological capabilities, but also by how they manage social, ethical, and governance risks. A socio-technical approach that balances innovation with human values needs to be used as a foundation. The smart cities of the future should not be seen simply as a technology project, but as an ecosystem that must maintain sustainability, social justice, and citizen participation. In this way, AI and robotics can truly become instruments that

[22] Nadia Nedjah, Ahmed A. Abd El-Latif, Brij B. Gupta, and Luiza M. Mourelle, eds. *Robotics and AI for Cybersecurity and Critical Infrastructure in Smart Cities*. Vol. 1030. Springer Nature, (2022).
[23] Federico Cugurullo. "Urban artificial intelligence: From automation to autonomy in the smart city." *Frontiers in Sustainable Cities* 2 (2020): 38.
[24] Victor Chang. "An ethical framework for big data and smart cities." *Technological Forecasting and Social Change* 165 (2021): 120559.

support sustainable development goals and improve the quality of life of urban communities.

6. Conclusion

The research highlights that artificial intelligence (AI) and robotics have a central role in smart city strategies, with a focus on automation, governance, education, infrastructure, and mobility. The results of the analysis show that this technology is able to improve the efficiency of public services, strengthen government transparency, and support environmental sustainability. Some cities have shown how technology can be applied on a different scale to address complex urbanization needs. However, behind these opportunities, there are a number of serious challenges that need to be addressed. Automation has the potential to replace human work, while algorithm-based decision-making can create bias and reduce citizen participation in democratic processes.

In addition, privacy and ethical issues are aspects that cannot be separated from the discourse of smart cities, considering the large amount of citizen data collected. Thus, sustainable smart city development requires a balance between technological innovation and human values. A socio-technical approach that emphasizes regulation, ethics, and social inclusion is key for AI and robotics to function as instruments that truly serve society. Only in this way can smart cities thrive as fair, adaptive and sustainable living spaces.

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