Artificial Intelligence of Things and Smart City Sustainability: Towards a Multidimensional Framework

Soukaina Ait Bahado [1*], and *Siham* Hamdani[1]

[1]Interdterdisciplinary Research Laboratory in Economics, Innovation, and Organizational Management, ENCG CASABLANCA, Hassan II University of Casablanca.
[2]Interdterdisciplinary Research Laboratory in Economics, Innovation, and Organizational Management, ENCG CASABLANCA, Hassan II University of Casablanca.

Abstract. Research focusing on the adoption of artificial intelligence of things (AIoT) solutions in urban digitalization contexts address technological, strategic, and institutional levers separately. The key contribution of this study is a conceptual model grounded in dynamic capabilities theory, where these dimensions are blended to capture AIoT roles in establishing smart city sustainability. Specifically, AIoT is conceptualized as a facilitator that supports cities' sensing, seizing, and reconfiguring capabilities. Key technological, strategic and institutional factors shaping AIoT as a player to enhance urban sustainability are identified. Implications for AIoT application in smart cities and its importance for improved and sustained urban governance are also presented.

1 Introduction

Urban population is expected to reach 68% by 2050 [1]. This rapid growth puts pressure upon infrastructure systems, energy, mobility, waste management, and air quality. In other words, cities must optimize natural resource usage, limit greenhouse gas emissions and build resilience to climate change impacts. More specifically, digitization through the integration of artificial intelligence of things (AIoT) has become a major player in establishing reliable and compatible infrastructure, as well as big data management and cybersecurity. Therefore, municipalities share today the responsibility of delivering equitable public services, minimizing digital disparities and protecting citizens' personal information. This research addresses the fragmentation of scientific literature. Only a few studies examine the social, environmental, and economic dimensions of AIoT in smart cities simultaneously. Interoperability and standardization of technologies remain understudied, hindering the widespread adoption of AIoT solutions. Furthermore, ethical and regulatory issues are often addressed in isolation, without considering the prerequisites for sustainable large-scale implementation. There is therefore a lack of an integrative framework in the literature that simultaneously links technological levers, organizational capabilities, and institutional requirements for urban sustainability. This gap currently limits the systemic understanding of the actual contribution of AIoT to sustainable smart cities. This study is motivated by the lack of integrative research and aims to answer the following question: how does artificial intelligence of things (AIoT) contribute to the sustainability of a smart city? The aim is to develop an integrative conceptual framework combining AIoT technological capabilities with urban sustainability goals in three dimensions: the optimization of urban resources through smart systems (water, energy, and waste) via AI and connected objects, the reduction of social and environmental inequalities and the improvement of climate resilience, interoperability and standardization of AIoT infrastructure for large-scale use. The major contribution of this study is to propose an original multidimensional framework linking the technological, organizational, and institutional levers needed to understand and operationalize the role of AIoT in urban sustainability. This framework is filling an important gap in literature as it remains fragmented and dominated by unidimensional analyses. The paper is organized as follows. First, the concepts of smart city sustainability, AIoT, and sustainable urban development are defined. Next, an integrated conceptual model grounded in dynamic capabilities theory is proposed. Finally, the paper discusses contributions to literature and outlines implications for researchers and managers.

2 Conceptual Background

2.1 Definition of key concepts

2.1.1 Sustainable smart cities

* Corresponding author: author@email.org

Sustainable smart cities may be defined as an urban model which integrates sophisticated information and communication technologies that respect the principles of sustainability, through an environmental approach and social and economic equity [2]. In contrast to the broad technology-driven perception which characterized the early days of the smart city movement, the concept of a sustainable smart city places priority on resilience, quality of life, and citizen participation [3]. In fact, sustainable smart city development depends on creating an urban ecosystem that considers the social, ecological, and economic factors of urbanization and uses technology like an engine that optimizes resources, reduces the ecological and carbon footprint, and fosters participatory governance [4]. For authors in [5], this approach is intended to foster and develop a resilient sustainable urban environment to climate change and social and economic risks. It is at the same time a driver of innovative solutions for the transition to a green economy.

2.1.2 Artificial Intelligence of Things (AIoT)

Artificial intelligence of things refers to the strategic synergy between artificial intelligence (AI) and internet of things (IoT) technology. Authors in [6] do not clearly define AIoT. However, their study suggests that AIoT may serve as a driving force in developing smart city initiatives by overcoming the limitations of AI and IoT and achieving large-scale implementation. Therefore, by combining the learning and reasoning capabilities of AI with IoT devices, smarter, more adaptable, and more efficient urban systems can be implemented [6]. According to de Freitas and colleagues [7], AIoT refers to the use of machine learning in conjunction with IoT devices to create a new environment for IoT devices to provide cognitive capabilities and making decisions. This technological combination paves the way for intelligent and personalized solutions, particularly in the field of assistive technologies, where it helps to improve the autonomy and quality of life of users [7]. Thus, AIoT may be understood as an intelligent cyber-physical ecosystem that is based on the convergence of AI and IoT and facilitates the collection, analysis, and contextual use of data for autonomous, adaptive, and sustainable decision- making.

2.1.3 Sustainable urban development

Sustainable urban development is a comprehensive approach aiming to build cities which are environmentally, economically and socially sustainable. In order to define this concept, Trindade and colleagues [8] describe sustainable urban development in terms of three interdependent pillars: environmental, social and economic [8]. According to these studies, balancing them guarantees urban sustainability. Bibri and Krogstie [9] explored these pillars in smart cities, where technological innovation and data-driven governance improve how they work and how resilient they are [9].

Sustainable urban development seeks to reduce the ecological footprint and promote renewable energy. Its social dimension promotes inclusion, citizen participation, and spatial justice, while economically, it enhances responsible and innovative growth models that foster long-term prosperity. Consolidating these pillars into an integrated approach implies the fulfillment of the economic, social and environmental needs of cities. This ensures that they are sustainable and provide welfare for all citizens.

2.2 Integrating AIoT into sustainable smart cities

The primary focus of this research on urban transformation is the convergence between smart and sustainable cities, artificial intelligence of things (AIoT), and sustainable urban development as evidenced both by recent publications in Scopus and Web of Science indexed journals. Even though they were developed in different areas, all three concepts mutually strengthen each other through technological integration and systemic sustainability. The concept of sustainable smart cities is defined as an urban environment using digital technologies to improve quality of urban life, economic competitiveness, and environmental performance [10]. Combining artificial intelligence (AI) analytics power with the Internet of Things (IoT) extensive connectivity, AIoT plays a key role in this perspective through the collection, interpretation, and intelligent use of vast amounts of urban data [11]. Integrating AIoT into smart cities creates operational synergies favoring sustainable urban development goals. An example of its application is the optimization of natural resource management (energy, water, mobility, waste) through real-time monitoring and predictive data analysis. More specifically, connected water management systems, can detect leaks in distribution networks and automatically adjust supply to limit losses. Meanwhile, smart waste collection devices use containers equipped with sensors to optimize collection routes and reduce fuel consumption. From a citizen perspective, this can translate into fewer service disruptions such as faster leak detection, and cleaner neighborhoods due to adaptive collection schedules. These capabilities to anticipate and adapt urban policies by using dynamic indicators help to improve sustainable planning and infrastructure resilience at the same time. Together with digital twins, AIoT allows to virtualize urban environments and permits planners to perform simulations to inform proactive decision-making in response to a variety of environmental, social and operational challenges.

Despite the growth in existing research around AIoT initiatives, it remains a fragmented and mainly technical field of investigation without a unified conceptual framework integrating technological, organizational, and institutional dimensions for urban sustainability. Consequently, there is always a theoretical gap linking AIoT with sustainable smart cities and sustainable urban development.

3 Theoretical foundations based on dynamic capabilities theory and AIoT

3.1 Dynamic capabilities and the integration of AIoT in smart urban systems

In accordance with the theory of dynamic capabilities [12], organizations in smart city contexts need to develop three key capabilities to remain competitive and adapt to changing environments. First of these is sensing, which means the ability to identify technological opportunities and environmental challenges using urban data analytics, artificial intelligence, and advanced observation tools. Next is seizing. It consists of leveraging these opportunities to develop and deploy AIoT solutions that satisfy sustainability criteria in terms of energy efficiency, mobility, and urban quality of life. Finally, reconfiguring reflects the ability for cities to continually reorganize their technology infrastructures, organizational systems, and public policies in response to evolving sustainability requirements and urban complexity, transformation or change.

The use of AIoT plays a central role in terms of optimizing energy consumption, monitoring air quality, modernizing public transportation, and promoting proactive citizen participation [11]. Therefore, mobilizing the dynamic capabilities theory allows us to link cities' organizational capabilities to AIoT technologies, providing us with a foundation for understanding what factors enable successful adoption and performance of sustainable AIoT. While there is considerable research on AIoT in smart cities, many of these studies focus on one of the three levers of this complex urban system: technological, strategic, and institutional. Such fragmentation in literature displays the need for a unified framework enabling cities to maximize long- term benefits of AIoT use.

3.2 Integrated conceptual model

As shown in Figure 1, AIoT helps make smart cities more sustainable through an integrated conceptual model that describes how technology, governance, and urban impact interact. According to dynamic capabilities theory [12], organizations have to develop the capacities for anticipation, action, and reorganization to respond effectively to changing demands in their environment. These capabilities allow urban environments to use AIoT to optimize infrastructure efficiency and enhance citizens' quality of life at the same time as promoting equitable and resilient development models. The model below identifies three major areas of focus supporting cities' sensing, seizing, and reconfiguring capabilities. For sensing, technology comprises the fundamental building blocks of a successful AIoT infrastructure including interoperability, data analytics, and energy efficiency. For seizing, strategic levers that drive the AIoT solutions include sustainable urban planning, lifecycle management, and increased collaboration between the public and private sectors to create coherent policies aimed at citizen well-being. Lastly, for reconfiguring, prior research highlights [13] that institutional levers primarily involve the creation of policy instruments, data protection, as well as citizen engagement. This creates awareness and stimulates acceptance for new technology, not to mention bridging geographical disparities. These three levers together offer a relevant framework for analysis, especially for the key actors in the city. It is a facilitator of effective and sustainable AIoT in their cities. This would relate to issues of compatibility, security regarding management of data, and differences based on geographic locations. In that, it is a pertinent instrument for formulating a vision regarding sustainable governance of cities through the concept of AIoT.

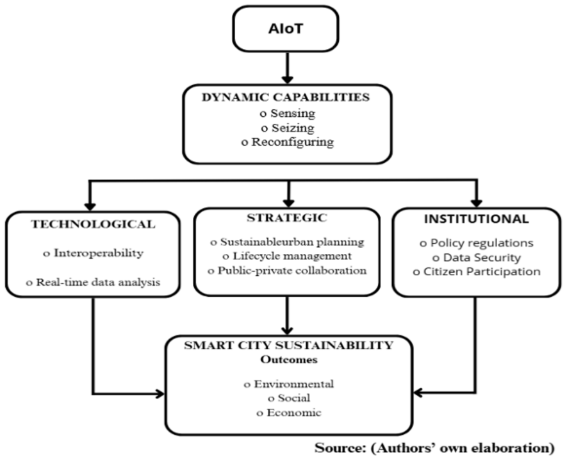

Fig. 1. Integrated conceptual model of AIoT for smart city sustainability.

Beyond structuring the technological, strategic, and institutional dimensions, the proposed framework also clarifies how AIoT-enabled capabilities relate to sustainability outcomes. Environmentally, detection and data analysis systems powered by AIoT allow cities to monitor energy consumption, traffic congestion, and air quality in real time. For example, smart traffic management systems can dynamically regulate vehicle flows, reducing fuel consumption and CO_2 emissions. Similarly, smart grids supported by AIoT contribute to greater energy efficiency and optimized resource use [14]. From a social perspective, strategic and institutional mechanisms such as citizen participation platforms and data governance policies promote inclusion and transparency. For example, digital urban dashboards that allow residents to report malfunctions or environmental concerns strengthen civic engagement and improve the responsiveness of public services, contributing to quality of life and reducing territorial inequalities [15]. Economically, AIoT-enabled lifecycle management tools and public-private partnerships facilitate predictive maintenance of infrastructure such as transportation networks and water supply systems. This reduces operating costs, increases infrastructure resilience, and strengthens long-term urban competitiveness. These examples illustrate how the alignment of dynamic capabilities and AIoT technologies translate into tangible, multidimensional sustainability outcomes in the context of smart cities.

4 Discussion

The developed multidimensional model that draws together technological determinants, dynamic capabilities, and institutional structures, serves as a comprehensive approach to understand how AIoT impacts urban sustainability. These dynamics influence environmental efficiency, social inclusiveness, and economic sustainability within smart city ecosystems. The technological perspective alone is not sufficient to capture smart city sustainability, our model therefore attempts to show how these dimensions interact to induce changes in urban sustainability through AioT. Indeed, using the theory of dynamic capabilities, smart cities are viewed as organizational systems equipped with sensing, seizing, and reconfiguring capabilities allowing them to detect, capture, and transform their AIoT resources. Therefore, further research can focus on reevaluating the systemic role of AIoT in urban transformation towards more sustainable, and resilient. Practically, the model can drive AIoT investments which are coherent with sustainable and inclusive smart city development. Urban stakeholders can also derive insights for deploying AIoT systems in interoperable, secure and user-centered digital infrastructure. For example, they can invest in AIoT solutions that collect citizen feedback in real time, with the objective to enhance urban services and enable urban planners to adapt their decision accordingly.

5 Conclusion

This paper proposes an integrated conceptual model that contributes to literature through exploring the role of AIoT in smart city sustainability. Through mobilizing dynamic capabilities theory, this model suggests that AIoT drives cities' sensing, seizing, and reconfiguring capabilities with regard to technology, urban strategies, and institutional instruments respectively. In fact, these levers are consolidated within the model, while most existing studies on AIoT and smart cities address them separately. For policymakers and urban actors, this study has the potential to support investments in AIoT solutions, as well as their effective and sustainable deployment. However, this work's major limitation is the absence of empirical validation. Future research could therefore focus on testing the proposed model through empirical studies, such as case studies or quantitative analysis.

References

1. C. Weil, S.E. Bibri, R. Longchamp, F. Golay, A. Alahi, Urban Digital Twin Challenges: A Systematic Review and Perspectives for Sustainable Smart Cities. Sustain. Cities Soc. 99, 104862 (2023). https://doi.org/10.1016/j.scs.2023.104862
2. Z. Allam, P. Newman, Redefining the Smart City: Culture, Metabolism and Governance. Smart Cities 1, 4–25 (2018). https://doi.org/10.3390/smartcities1010002
3. N. Tcholtchev, I. Schieferdecker, Sustainable and Reliable Information and Communication Technology for Resilient Smart Cities. Smart Cities 4, 156–176 (2021). https://doi.org/10.3390/smartcities4010009
4. S.B. Issa Zadeh, C.L. Garay-Rondero, Enhancing Urban Sustainability: Unravelling Carbon Footprint Reduction in Smart Cities through Modern Supply-Chain Measures. Smart Cities 6, 3225–3250 (2023). https://doi.org/10.3390/smartcities6060143
5. B.K. Kuguoglu, H. van der Voort, M. Janssen, The Giant Leap for Smart Cities: Scaling Up Smart City Artificial Intelligence of Things (AIoT) Initiatives. Sustainability 13, 12295 (2021). https://doi.org/10.3390/su132112295
6. M.P. de Freitas et al., Artificial Intelligence of Things Applied to Assistive Technology: A Systematic Literature Review. Sensors 22, 8531 (2022).https://doi.org/10.3390/s22218531
7. E. Trindade et al., Sustainable development of smart cities: A systematic review of the literature. J. Open Innov. Technol. Mark. Complex.3(2017). https://doi.org/10.1186/s40852-017-0063-2
8. S.E. Bibri, J. Krogstie, Smart Sustainable Cities of the Future: An Extensive Interdisciplinary Literature Review. Sustain. Cities Soc. 31 (2017). https://doi.org/10.1016/j.scs.2017.02.016
9. A. Janik, A. Ryszko, M. Szafraniec, Scientific Landscape of Smart and Sustainable Cities Literature: A Bibliometric Analysis. Sustainability 12, 779 (2020). https://doi.org/10.3390/su12030779
10. S.E. Bibri, J. Huang, Artificial intelligence of things for sustainable smart city brain and digital twin systems. Environ. Sci. Ecotechnol. 26, 100591(2025). https://doi.org/10.1016/j.ese.2025.100591
11. D.J. Teece, G. Pisano, A. Shuen, Dynamic capabilities and strategic management. Strateg. Manag. J. 18, 509–533 (1997).
12. M. Chong et al., Dynamic capabilities of a smart city: An innovative approach to discovering urban problems and solutions. Gov. Inf. Q. 35, 682–692 (2018).
13. A.P. Chokki, A. Simonofski, B. Frénay, B. Vanderose, Engaging Citizens with Open Government Data: The Value of Dashboards Compared to Individual Visualizations. Digit. Gov. Res. Pract. 3, 21 (2022).https://doi.org/10.1145/3558099
14. S.R. Ahmed et al., Machine Learning for Sustainable Power Systems: AIoT-Optimized Smart-Grid Inverter Systems with Solar Photovoltaics, in Forthcoming Networks and Sustainability in the AIoT Era (Springer, Cham, 2024), 368–378. https://doi.org/10.1007/978-3-031-62881-8_31
15. United Nations, 68% of the world population projected to live in urban areas by 2050, says UN, United Nations (2018). https://www.un.org/uk/desa/68-world-population-projected-live-urban-areas-2050-says-un