

MEMORIE GEOGRAFICHE

XIV Giornata di studio "Oltre la globalizzazione"
Firenze, 6 dicembre 2024

Transizioni/ *Transitions*

a cura di
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Transizioni/Transitions è un volume delle Memorie Geografiche della Società di Studi Geografici

<http://www.societastudigeografici.it>

ISBN 978-88-94690187

Numero monografico delle Memorie Geografiche della Società di Studi Geografici
(<http://www.societastudigeografici.it>)

Certificazione scientifica delle Opere

Le proposte dei contributi pubblicati in questo volume sono state oggetto di un processo di valutazione e di selezione a cura del Comitato scientifico e degli organizzatori delle sessioni della Giornata di studio della Società di Studi Geografici

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PRESENTAZIONE

Tutte le transizioni conviene che sieno fatte adagio; perché, se si fanno a un tratto, di là a brevissimo tempo si torna indietro, per poi rifarle a grado a grado. Così è accaduto sempre. La ragione è, che la natura non va a salti, e che forzando la natura, non si fanno effetti che durino. Ovvero, per dir meglio, quelle tali transizioni precipitose sono transizioni apparenti, ma non reali.

Giacomo Leopardi, *Operette morali*

It is tempting to write the history of technology through products: the wheel; the microscope; the airplane; the Internet. But it is more illuminating to write the history of technology through transitions: linear motion to circular motion; visual space to subvisual space; motion on land to motion on air; physical connectivity to virtual connectivity.

Siddhartha Mukherjee, *The Gene: An Intimate History*

Con grande piacere presento il XXVIII volume delle Memorie Geografiche, che raccoglie le rielaborazioni della XIV edizione della Giornata di studio “Oltre la Globalizzazione”, dedicata al tema “Transizioni/Transitions”, svoltosi a Firenze il 6 dicembre 2024, promossa dalla Società di Studi Geografici e organizzate dal Dipartimento di Scienze per l’Economia e l’Impresa (DISEI) dell’Università di Firenze.

La XIV edizione delle Giornate ha visto una partecipazione eccezionale, testimoniata dalle 167 comunicazioni raccolte in questo volume, raggruppate in 29 sessioni che hanno saputo raccogliere la sfida del confronto con una parola chiave impegnativa, quale “transizioni” affrontato attraverso una pluralità di prospettive e tematismi.

Questo numero delle Memorie Geografiche riveste un’importanza simbolica particolare. Francesco Dini, che ha proposto e coordinato le “Giornate di Studi Oltre la Globalizzazione” e che introduce il volume, ha concluso il suo percorso accademico nell’autunno 2025. A lui vanno in primis i nostri ringraziamenti per tutto il contributo che ha dato in molti anni alla Società di Studi Geografici, alla Rivista Geografica Italiana, alle Memorie Geografiche, sperando di poter contare ancora a lungo sul suo contributo attivo, critico ed innovativo.

Da parte mia e di tutto il Consiglio della SSG va inoltre il più sentito ringraziamento alle organizzatrici, agli organizzatori e a tutto il comitato locale, per lo stimolante e partecipato evento e per questo volume che arricchisce e qualifica ulteriormente la serie delle Memorie Geografiche.

Firenze-Torino, dicembre 2025

*Egidio Dansero
Presidente della Società di Studi Geografici*

SIMONA EPASTO*

BLOCKCHAIN AND AI FOR SMART CITY GOVERNANCE: INCLUSIVE MODELS, ETHICAL CHALLENGES, AND GEOGRAPHICAL IMPLICATIONS

1. INTRODUCTION. – The concept of the smart city (SC) is central to contemporary urban strategies, where digitalisation plays a key role in enabling efficient and sustainable management. The deployment of digital technologies has paved the way for new models of urban governance, in which Artificial Intelligence (AI) and Blockchain Technology (BCT) emerge as essential tools for ensuring transparency, security, and sustainability in decision-making processes and public services (Biasin and Delle Foglie, 2024).

However, the integration of AI-BCT goes beyond a mere technological evolution: it represents a true paradigm shift in urban governance. The ability of BCT networks to ensure data immutability and decentralised decision-making processes complements the analytical power of AI, which can process vast amounts of data in real time, detect complex patterns, and provide predictive support for city management (Kuznetsov *et al.*, 2024). This technological convergence lies at the heart of contemporary urban policy, as in the EU-funded TRUST project, which aims to strengthen digital trust between citizens and institutions (TRUST Project, 2023).

At the same time, the dissemination of these technologies raises ethical, social, and regulatory concerns. The digital transformation of cities requires reflection on its impact on inclusion and the social fabric. While AI-BCT promise transparency and efficiency, they also risk reinforcing digital inequalities, excluding from the opportunities of SC those segments of the population who lack the skills or resources to access digital services (Lutz, 2019). This is especially relevant in EU cities, where the push for digitalisation must align with fundamental rights and compliance with existing regulations, such as the General Data Protection Regulation (GDPR) and the digital governance directives established by the European Commission (CINEA, 2024).

Within this framework, the present research aims to explore the transformative potential of AI-BCT integration in urban governance, analysing its implications in terms of digital trust, cybersecurity, and social sustainability. Through both theoretical and empirical analysis, the study investigates the main implementation models adopted by European cities, with particular focus on the cases of Tallinn, Vienna, and Barcelona, which are currently experimenting with innovative solutions for more transparent and decentralised urban management (European Commission, 2024).

From a methodological perspective, the research adopts an interdisciplinary approach, combining an analysis of the main theoretical references with the study of operational best practices. The Quadruple Helix Model (QHM) provides the conceptual framework to understand the role of collaboration among public institutions, the private sector, academia, and citizens in building an urban ecosystem based on decentralised and participatory technologies (Carayannis and Campbell, 2009). By examining current implementations of AI and BCT in SC, this study seeks to contribute to the scientific debate and offer useful insights for the development of governance strategies that are innovative, inclusive, and resilient.

2. THEORETICAL FRAMEWORK AND CONCEPTUAL BACKGROUND.

2.1 *SC and digital transformation.* – In recent decades, the concept of the smart city has acquired a central role in urban development strategies, outlining a model in which digitalisation becomes a key tool for achieving more efficient and sustainable urban management. SC are technological ecosystems where sustainability, participatory governance, and digital innovation intertwine to improve citizens' quality of life and enhance urban resilience (Albino *et al.*, 2015; Chourabi *et al.*, 2012).

Academic literature has progressively refined the definition of SC, highlighting their multidimensional character: while technological infrastructures such as the Internet of Things (IoT), big data, and AI are crucial for advanced urban management, it is equally essential that these innovations be integrated into a holistic



vision of the city, one that encompasses environmental, economic, and social dimensions (Komninos, 2013). In this perspective, the Quadruple Helix Model (QHM) emerges as one of the most influential paradigms in the governance of SC, as it emphasises the importance of synergy between government, industry, academia, and citizens in the co-creation of innovation (Carayannis and Campbell, 2009; Kuzior and Kuzior, 2020).

This approach responds to the need for participatory and decentralised governance, in which different actors co-create solutions to urban challenges. European cities are adopting this model, as demonstrated by recent initiatives in Lyon, Valencia, Milan, and Vienna (State of the European Smart Cities, 2024).

GeoAI (Geospatial Artificial Intelligence) is gaining increasing importance as an emerging discipline that combines AI tools with spatial data for predictive analysis, urban resilience, and privacy protection (Hu *et al.*, 2024; Goodchild *et al.*, 2023), facilitating the monitoring and predictive management of urban dynamics. However, for GeoAI applications to be effective, a clear regulatory framework and governance mechanisms that ensure equity, transparency, and security in decision-making processes are required. Unsurprisingly, several European strategies for territorial resilience and ecological transition advocate using GeoAI tools, given their capacity to offer advanced location intelligence, support the predictive management of resources, and anticipate environmental and economic vulnerabilities (European Commission, 2024; FBK, 2024).

2.2 The role of trust in digital governance. – A key element of the digital transformation is trust in decision-making technologies. Blockchain Technology (BCT) has been widely recognised as a key enabler for strengthening trust in SC, due to its decentralised, immutable, and transparent features (Biasin and Delle Foglie, 2024). In particular, the ability to record transactions securely and immutably on a distributed ledger enhances transparency in urban data management and public service provision.

At the same time, AI plays a fundamental role in optimising urban resources and enabling intelligent decision-making, by forecasting traffic flows, improving energy management, and supporting the development of urban policies grounded in advanced data analysis. However, the increasing automation of decision-making processes raises significant ethical issues, related to the need to ensure that algorithms are fair, transparent, and non-discriminatory (Cugurullo, 2020).

At the regulatory level, the European framework is shaped by the General Data Protection Regulation (GDPR) and a range of initiatives aimed at ensuring that using AI in cities complies with the principles of transparency, accountability, and the protection of digital rights (European Commission, 2024). In response to these needs, the TRUST project – “digital TuRn in Europe”, funded by the European Union – has developed a framework for AI-BCT integration that aims to reinforce digital trust and ensure a balance between technological innovation and citizens’ rights (TRUST Project, 2023).

This intersection brings opportunities and challenges for SC governance. Urban data management, for instance, must be based on criteria of security and transparency, avoiding the risk of pervasive surveillance and protecting citizens’ privacy. At the same time, the adoption of these technologies must occur within an inclusive governance framework, involving citizens and stakeholders in key decisions concerning the digital transformation of cities (Lutz, 2019).

3. METHODOLOGY. – The approach adopted is interdisciplinary, drawing from urban planning, geography, computer engineering, and innovation studies. This methodological choice is essential to grasp the complexity inherent in the AI-BCT convergence within the domain of urban governance, particularly in European SC.

The analysis proceeds from the premise that SC must be understood beyond their technological dimension, encompassing social, ethical, and territorial implications. Therefore, a qualitative method has been employed, combining literature review and the analysis of European best practices, with an integration of GeoAI and Digital Innovation Hubs (DIHs). The first phase of the research involved the identification and analysis of significant cases of advanced digital governance, with particular attention to the e-governance models implemented in cities such as Tallinn, Vienna, and Masdar City. These cases exemplify the strategic use of AI-BCT aimed at enhancing transparency, security, and civic participation.

Notably, the Estonian experience stands out for its adoption of a decentralised digital infrastructure based on BCT, which ensures that citizens retain direct control over their personal data, while Masdar City functions as a technological innovation laboratory where AI and sustainable solutions are integrated into the daily management of urban resources.

From a conceptual perspective, the methodology draws upon the Quadruple Helix Model (QHM), already discussed in previous sections, which provides a framework for understanding the collaborative dynamics

among public and private actors, universities, and citizens. Within this framework, DIHs play a crucial role as innovation intermediaries, promoting the dissemination of emerging technologies and the co-creation of solutions for SC. They act as connectors among various stakeholders, facilitating the adoption of technologies such as AI and BCT by local communities and public administrations (Lepore *et al.*, 2023).

An additional methodological tool is GeoAI (Geospatial Artificial Intelligence). This approach enables real-time monitoring of complex urban phenomena, supporting data-driven decision-making processes and enhancing territorial resilience (Paolanti *et al.*, 2022).

4. RESULTS AND DISCUSSION.

4.1 Digital governance and trust. – The integration of AI-BCT within SC is emerging as one of the key drivers for renewing urban governance processes. Through a critical analysis of current implementation models and ongoing projects, it becomes evident that their synergistic application holds significant potential for strengthening trust in decision-making processes, fostering governance that is collaborative, transparent, and participatory.

TRUST represents one of the most emblematic examples of this approach. Within the scope of its activities, it has been demonstrated that the combined adoption of AI and BCT helps mitigate informational asymmetries and ensures traceability of administrative decisions, thereby reinforcing trust among citizens, institutions, and businesses. The immutability of data ensured by BCT, together with the predictive and adaptive capabilities of AI, enables the construction of a governance model based on decentralised decision-making processes that enhance value co-creation among various urban stakeholders (Kuznetsov *et al.*, 2024).

However, the emergence of these new technologies also raises important social concerns, particularly regarding the risk of digital exclusion for vulnerable segments of the population. Digital inequalities no longer relate solely to disparities in access to technology but also include differences in digital skills and in the impacts of automated systems. As automation increases, it is essential to avoid worsening socio-economic inequalities.

Another critical aspect concerns the need to actively involve citizens in decision-making processes related to the digitalisation of cities. Findings from McKinsey's *Smart Citizen* report confirm that the effective adoption of smart technologies is linked to the level of citizen participation and awareness (Woetzel and Kuznetsova, 2018). Without appropriate tools for inclusion and digital literacy, governance risks being perceived as distant and opaque, thereby undermining the very principle of trust upon which the smart city paradigm is based.

In this regard, the contribution by Biasin and Delle Foglie (2024) proves particularly relevant. The authors highlight how the application of BCT in SC can serve as a catalyst for the development of more inclusive and sustainable communities if policies are adopted to balance technological efficiency with the protection of digital rights and the promotion of social equity.

Overall, the results of the analysis confirm that the effectiveness of digital governance does not depend solely on technological advancement, but is closely tied to the ability of urban administrations to integrate principles of transparency, participation, and inclusion, in line with the foundational values of the EU and with current regulations on data protection and digital rights (European Commission, 2024).

4.2 Transparency and security. – The issue of transparency and security represents one of the most sensitive nodes in the contemporary debate on the future of SC and using emerging technologies in urban governance. In this context, BCT and AI are not merely tools for the digitalisation of urban services, but act as true instruments of trust and control, with the potential to profoundly reshape the relationships between citizens, institutions, and urban infrastructures.

BCT ensures data immutability and traceability in key sectors such as resource management and e-voting. The ability to register every transaction in a transparent and verifiable way for all stakeholders reduces opacity and fraud, thereby strengthening trust in institutions and urban governance. Unsurprisingly, many European cities are experimenting with blockchain-based systems for the management of essential public services, promoting greater administrative accountability (Kuznetsov *et al.*, 2024).

At the same time, using AI for predictive analysis is becoming an indispensable component in enhancing urban safety and preventing complex crises. As noted by Cugurullo (2020), the introduction of AI into urban decision-making processes is transforming the very fabric of city governance, leading toward advanced forms of automation beyond service optimisation. AI helps monitor risks, manage flows, and coordinate emergency responses, thus serving as a key instrument for ensuring resilient and proactive governance.

However, the rise of these tools also raises crucial questions regarding data management, privacy protection, and the potential for urban surveillance. As recent literature has pointed out (Lazzeroni, 2023; Romano and Lazzeroni, 2024), algorithmic automation and AI risk generating new forms of spatial asymmetry and data-driven discrimination, further amplifying existing inequalities. Transparency is more than visibility: it is a principle of equity and accessibility, and the protection of all citizens' digital rights.

The main challenge thus lies in the ability to combine the potential of AI and BCT with a governance model that is at once effective, secure, and inclusive. Only through the conscious and participatory design of digital infrastructures can SC avoid becoming spaces of pervasive control and opaque surveillance, and instead foster the emergence of inclusive urban communities, attentive to privacy, and grounded in digital responsibility.

4.3 Case studies and best practices. – The growing complexity of urban systems, combined with the need to ensure sustainability, security, and participation in decision-making processes, has led many cities to experiment with the integration of BCT and AI into their governance frameworks. In the EU, Tallinn has adopted a model oriented towards algorithmic governance, combining transparency with automation, while Vienna has stood out for its integration of data governance and spatial justice. In both cases, the application of GeoAI tools – such as predictive analysis of geospatial data and automated pattern detection through deep learning – has enabled more effective resource allocation and adaptive planning, aligned with the challenges of ecological and digital transitions (Pierdicca and Paolanti, 2022; Boutayeb *et al.*, 2024).

The analysis of case studies and international best practices confirms that these technologies are not merely operational tools, but enablers of innovative urban management models based on transparency, traceability, and social inclusion. By reviewing the most significant practices, replicable guidelines emerge that support the transition from traditional governance to a collaborative and resilient approach, capable of engaging citizens, businesses, administrations, and academia in designing the cities of the future.

A paradigmatic example of successful BCT implementation is offered by Estonia, recognised as a pioneer in the development of advanced e-governance solutions. Estonia's X-Road ensures secure data interoperability through BCT, supporting services from digital identity to e-voting. Thanks to the decentralisation of databases and distributed encryption, Estonia has ensured administrative transparency, reduced the risk of manipulation, and strengthened citizens' trust in public institutions (TRUST Project, 2023; Romeo *et al.*, 2023a; 2023b).

Another successful example outside the EU is Masdar City, a model of environmental and technological innovation. In this advanced urban laboratory, AI is employed for the autonomous management of city infrastructures – from energy to mobility. AI monitors flows and optimises resource use, reducing environmental impact and promoting predictive and adaptive governance (Cugurullo, 2020). Although it is situated in a different context from that of Europe, this case provides valuable insights into how AI can be integrated to enhance the resilience and efficiency of urban services.

Within the European landscape, the conceptual reference is represented by the Quadruple Helix Model (QHM). The European Innovation Partnership on SC and Communities (EIP-SCC) is one of the most relevant examples, offering a framework for the implementation of projects aimed at promoting sustainability and inclusiveness through the adoption of emerging technologies (CINEA, 2024). DIHs facilitate the dissemination of emerging technologies and collaboration between institutions, businesses, and citizens (Lepore *et al.*, 2023), acting as catalysts for innovation and experimentation. They promote the adoption of participatory digital governance models and ensure that even less developed regions can access the opportunities offered by digitalisation.

Among the most significant experiences are several emblematic cases that demonstrate the transformative potential of BCT-AI integration in urban governance. TRUST project cases show how AI-BCT enhance transparency, services, and civic participation.

The main best practices are summarised in Table 1, which provides a comparative overview of the most relevant applications of BCT and AI in EU urban governance.

The analysis presented demonstrates that the integration of AI and BCT goes beyond mere technological adoption, amounting to a structural transformation of urban governance. To fully appreciate the strategic value of these experiences, it is useful to adopt a transversal reading of the benefits generated, structured around four key dimensions: transparency, security, inclusiveness, and resilience. These dimensions represent the main areas of impact of emerging technologies in contemporary urban management. Table 2 summarises these key benefits and links them to the most relevant examples.

Tab. 1 - EU best practices in the integrated use of AI-BCT for public governance

Country/Region	Application Domain	Technology Used	Main Goals and Impacts
Estonia	E-Governance, e-Residency, digital identity	Blockchain	Strengthen trust in digital interactions through transparency and security; global model of digital society.
Sweden	Land registry	Blockchain	Improve transparency and efficiency in real estate transactions; reduce fraud and intermediaries.
Vienna (Austria)	Open Government Data	Blockchain	Ensure integrity and transparency of public data; increase civic trust in institutions.
Catalonia (Spain)	Public administration and electoral systems	Blockchain	Strengthen transparency in administrative and voting processes; ensure security and traceability.
France	Diploma certification	Blockchain	Prevent academic credential fraud; enhance trust in recruitment and selection processes.
Finland	Access to social services (KELA)	Artificial Intelligence	Improve efficiency, personalisation, and citizen satisfaction in public services.
Denmark	Company financial statement analysis (Business Authority)	Artificial Intelligence	Predict bankruptcy risks; reinforce the authority's role in economic stability.
Rotterdam (Netherlands)	Urban environmental monitoring	AI + IoT	Increase urban resilience through predictive analytics and data transparency; enable informed civic participation.

Source: our elaboration based on data from the TRUST project.

The comparative reading highlights the contribution of emerging technologies to equitable and sustainable urban governance. The analysis of these best practices, supported by the findings of the TRUST project, demonstrates that the effectiveness of AI-BCT integration in SC is linked to the capacity of public administrations to implement collaborative governance models that simultaneously ensure transparency, security, inclusion, and sustainability. As documented in the project reports (Romeo *et al.*, 2023a; 2023b), these experiences converge in shaping a digital ecosystem based on trust – capable of responding to contemporary challenges and promoting active and informed citizenship.

Tab. 2 - Impact dimensions of AI-BCT integration in urban governance

Dimension	Key Benefits	Relevant Examples
Transparency	Traceability of data and decision-making processes; fraud reduction.	TRUST project (supply chain and voting); Estonia (e-Governance); Vienna (Open Data).
Security	Information integrity, digital resilience, attack prevention.	Masdar City (AI infrastructures); Estonia (X-Road infrastructure); AI predictive systems.
Inclusiveness	Civic participation; reduction of the digital divide; co-creation.	TRUST (collaborative models); KELA (AI in social services); Vienna (equitable data access).
Resilience	Ability to respond to critical events and climate change.	Rotterdam (AI+IoT for environmental monitoring); GeoAI for predictive planning.

Source: our elaboration based on TRUST Project (2023); Cugurullo (2020); EIP-SCC (2024).

Finally, it is important to emphasise the geographical and geoeconomic implications of these processes. The growing adoption of AI and BCT risks exacerbating territorial disparities between highly digitalised urban areas and peripheral regions lacking the necessary infrastructures and skills. It is therefore essential that urban innovation policies be accompanied by cohesion strategies aimed at ensuring equitable access to emerging technologies, as reiterated in the EIP-SCC guidelines (CINEA, 2024).

5. CONCLUSIONS AND FUTURE IMPLICATIONS. – The analysis conducted has shown that the integration of AI and BCT is progressively reshaping the dynamics of urban governance. Through a critical review of key European and international experiences, it has emerged that the combined adoption of these technologies not only improves the efficiency of public services but also reinforces the principles of transparency, resilience, and inclusion – elements that are essential for sustainable and collaborative urban governance. In this perspective, GeoAI proves crucial in transforming geospatial data into predictive tools for urban governance, contributing to the development of more resilient, data-driven, and spatially aware cities (Goodchild *et al.*, 2023; Paolanti *et al.*, 2022).

First, BCT functions as an enabling technology for building a digital ecosystem based on trust. Its decentralised architecture ensures administrative traceability and data security, offering concrete solutions for transparent public service management and active citizen engagement. At the same time, AI contributes to the optimisation of urban resources and the anticipation of complex scenarios, facilitating the emergence of predictive governance capable of responding promptly to the needs of contemporary cities (TRUST Project, 2023).

However, the implementation of these technologies is not without challenges and critical issues. One of the most evident risks concerns the potential widening of digital inequalities, especially affecting social groups that, due to economic, cultural, or infrastructural reasons, lack the skills to access digital services. The divide now concerns the ability to interact critically with algorithmic systems (Lutz, 2019). In this context, there is a real risk that the digitalisation of cities could give rise to a new form of exclusion, further exacerbating existing asymmetries.

Another challenge lies in the need to provide cities with an updated and coherent regulatory framework capable of ensuring the protection of digital rights and personal data. While the EU has already launched significant initiatives in this direction – such as the GDPR, the Digital Services Act, and the AI Act – it is clear that the rapid pace of technological evolution requires constant regulatory updates to address the new challenges posed by automation and the decentralisation of decision-making processes (European Commission, 2024).

Future platforms must promote civic participation. Living Labs and Civic Tech are key tools for collaborative urban ecosystems and e-participation platforms represent crucial tools to facilitate dialogue among citizens, administrations, and businesses, promoting inclusive and transparent decision-making processes. The experience of European DIHs and projects funded under the Horizon Europe programme demonstrates that it is possible to adopt strategies that combine technological innovation with territorial cohesion, thereby reducing disparities between advanced urban centres and less digitalised peripheral areas.

Ultimately, the future of SC will depend on the ability of public administrations to manage the intersection between technology, participation, and social justice. Only through an integrated approach that balances technological efficiency with civil rights will it be possible to achieve truly sustainable and inclusive SC.

ACKNOWLEDGEMENTS. – This project has received funding from the European Union’s Horizon 2020 Research and Innovation Programme under the Marie Skłodowska-Curie grant agreement n. 101007820. This document reflects only the author’s view. The Research Executive Agency is not responsible for any use that may be made of the information it contains.

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SUMMARY: BTC and AI, often perceived as neutral tools for efficiency, emerge as key technologies for reshaping urban governance models. This study explores how their integration fosters transparency, resilience, and citizen participation, while also exposing new forms of digital inequalities. Through the analysis of the Quadruple Helix Model and best practices in Estonia, Vienna, and Masdar City, the research reveals how AI and BTC renegotiate the relationship between institutions and citizens. Ethical, regulatory, and social challenges are addressed, highlighting the need for collaborative platforms to promote inclusive and sustainable governance.

RIASSUNTO: *Blockchain e AI per la governance delle smart cities: modelli inclusivi, sfide etiche e implicazioni geografiche.* L'integrazione di BTC e AI nelle *smart cities* si configura come leva strategica per ripensare i modelli di governance urbana. L'articolo analizza come tali tecnologie, lungi dall'essere strumenti neutrali, diventino vettori di trasparenza e partecipazione, ma anche di nuove disuguaglianze digitali. Attraverso l'esame del Quadruple Helix Model e di esperienze europee (Estonia, Vienna, Masdar City), si evidenzia come AI e BTC rinegozino il rapporto tra istituzioni e cittadini. Vengono inoltre approfondite le sfide normative ed etiche, proponendo piattaforme collaborative per una governance resiliente e inclusiva.

Keywords: smart cities, BTC, AI, collaborative governance, digital inclusion, urban trust

Parole chiave: smart cities, BTC, AI, governance collaborativa, inclusione digitale, fiducia urbana

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