SOCIETÀMUTAMENTOPOLITICA
RIVISTA ITALIANA DI SOCIOLOGIA

Citation: d'Albergo, E., & Giovanelli, G. (2024). Urban Sustainability and the Local Politics of Digital Twins: the Cases of Bologna and Milan. Società*Mutamento*Politica 15(30): 65-78. doi: 10.36253/smp-15407

Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

Competing Interests: The Author(s) declare(s) no conflict of interest.

Urban Sustainability and the Local Politics of Digital Twins: the Cases of Bologna and Milan

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Abstract. To address the complexity of sustainable urban development, policymakers are making increasing use of digital technology tools, now including AI and urban digital twins (UDTs). The aims of the article are to shed light on the political implications of UDTs uses in urban policy and governance aimed at sustainability and to understand from a perspective of political sociology factors influencing processes of UDTs design and implementation. Research questions regard the local politics of UDTs for sustainability analyzed through the lenses of policy frames, contexts, regulation and data governance and value. Responses are based on evidence from the comparative analysis of two case studies: Bologna and Milan, carried out through desk and field research (analysis of documents and interviews). Local agencies lead to different approaches and, potentially, outcomes, made possible by the diversity and plasticity of UDT models, systems and purposes, as well as by the elasticity and adaptability to different spatial contexts of the policy paradigm of urban sustainability. Two patterns of the local politics of UDTs emerge in Bologna and Milan, in which above all the roles of public actors and businesses are different. Logics of action, practices and forms of coordination are transferred from the broader systems of urban governance and political economy to the more circumscribed systems of action of UDTs.

Keywords: urban sustainability, digital twins, urban policies, urban governance.

1. INTRODUCTION

The policy frame and goals of sustainable development and especially SDG 11 place in the foreground aims and actions to be carried out in cities, since urbanisation processes have made them places where the challenges of social, economic and environmental sustainability will be won, or lost. Agendas for urban sustainable development include a wide range of programs and measures, implemented locally in several fields of policy such as economic development, planning, mobility, housing and social policy, natural resources, energy and waste management.

To address the complexity of sustainable urban development, policymakers are making increasing use of digital technology tools, as observed over the past two decades in the context of smart cities. The "sustainable smart city" approach has recently been integrated with artificial intelligence (AI) systems in its main domains: mobility, education, healthcare, environ-

ment, governance, living and infrastructure, economy and urban security. These innovations include tools to support decision-making, such as urban digital twins (UDTs). Since the development of UDTs is just at an early stage, it is too early to base a critical analysis of how they impact on local political and administrative decision-making and sustainable development on empirical evidence. So, the aims of this article are to shed light on some of the political implications of UDTs' uses in urban policy and governance and to understand, from a perspective of political sociology, which factors so far have influenced the processes of UDTs design and implementation.

The resulting research questions regard the local politics of UDTs for urban sustainability and in particular the frames, contexts, regulation and data governance of UDTs projects. Responses are based on evidence from the comparative analysis of two case studies in Italy: Bologna and Milan, carried out through desk and field research.

The first section of the article reviews the current multidisciplinary literature on UDTs, providing a definition and describing their main characteristics, fields of use and modalities in supporting decision-making. The second section provides a summary of the scientific debate on the political implications of UDTs. Next, the theoretical approach of this paper, the research questions, methodology and field of analysis are presented. Section four provides a description of the two case studies, highlighting their main similarities and differences. Section five shows the main comparative results regarding the four issues analysed and outlines the characteristics of the two implementation models, which are discussed in the final section.

2. WHAT URBAN DIGITAL TWINS FOR SUSTAINABLE URBAN DEVELOPMENT ARE

The concept of digital twin (DT), first coined about 20 years ago in the industry sector, means a digital replica of a physical object, person, device, system, or place, with its spatial, social, or economic processes (Batty 2018; Deren *et al.* 2021; Charitonidou 2022). A DT makes it possible to observe changes, detect errors, make changes and corrections remotely, reduce risks in harsh environments (Allam and Jones 2021) and simulate the effects of human decisions regarding the original twin. On the one hand, DT technology has a significant impact also on the sustainability of industrial production, particularly in terms of reducing waste, energy consumption and environmental impact (World Economic Forum 2022). On the other hand, DTs are a cutting-edge technology for sustainability policies, as demonstrated by the European Commission's flagship project "Destination Earth", a highly accurate digital Earth model that can be used to simulate policies and actions to mitigate climate change. The European Commission Von del Leyen I (2019-2024) has set the course for the "Twin Transition", a term that highlights the opportunity to integrate the green and digital transitions to avoid the traps of parallel development and to promote synergies between policies and actions (Muench *et al.* 2022). To this end, DT technology provides to date the most advanced model for analysing interactions between the physical and virtual worlds in major natural and social phenomena (Nativi *et al.* 2021).

DTs focused on urban management (UDTs) started to be developed around 2018, also built on the knowledge gained with the development of smart cities. There are several types of UDTs, since their characteristics depend on their use and they are based on a lot of different data. Such "Big Data" can be provided by existing datasets, IoT and sensors, including smartphones, while UDTs feedback processes data (Deng *et al.* 2021) applying machine learning techniques for making predictions (Papyshev and Yarime 2021).

UDTs are not the only digital tool used in urbanism (Ferré-Bigorra *et al.* 2022). They are sometimes compared to cases and concepts such as: (i) urban (or city) brain, also integrating multi-source heterogeneous data through multi-perspective learning methods to do analysis, prediction, and intelligent intervention (Cugurullo 2021; Deng *et al.* 2021); (ii) the cognitive city, that is the interplay of humans and technology in smart city initiatives, augmenting cities' possibilities to learn and adapt to changes (Hämäläinen 2021); (iii) technologies of smart cities, which the debates around UDTs are closely related to (Charitonidou 2022).

For that very reason, even though they are still in an experimental research-action phase, UDTs make a paradigm shift in urban modelling practices and policies potentially possible. This could lead to governance by technology that, selecting and ordering information, has the power to emphasize certain aspects of the socio-technical assemblage in which it operates (Nochta *et al.* 2019).

There are several fields of use of UDTs for sustainable urban development (Deng *et al.* 2021; Charitonidou 2022; Allam and Jones 2021; Hämäläinen 2021; Yarime 2021; Alva *et al.* 2022; Suffia 2022), on wider (urban; metropolitan; regional) or narrower (district; neighbour; block) scales. Fields may include utilities, infrastructures, logistics (e.g. freight, reducing the undesirable effects of last mile deliveries, Marcucci *et al.* 2020), ener-

gy consumption, telecommunications, water, food and waste, disaster and security resilience, urban planning (e.g land use, urban development initiatives, building construction), mobility and transportation (e.g. traffic congestion and improved air quality, Nochta *et al.* 2019).

UDTs uses range from decision-making autonomy, normally regarding only short-term management of operational and maintenance systems to decision support in human strategic-level decision-making, even in the form of evaluations for the long-term future.

When used for decision support, which does not (yet) entail technology as an active stakeholder making decisions and shaping urban governance (Cugurullo *et al.* 2024), UDTs can provide policymakers – political authorities, private stakeholders, or citizens involved in practices of participatory democracy or civic engagement (Alva *et al.* 2022; Caprari *et al.* 2022) – with insights for capacity building and data-driven, evidence-based decision making (CABB 2019). This normally implies the reframing of high-level policy goals into practical policy and management problems. A model can suggest solution options (Nochta *et al.* 2021) by simulating alternative choices in a virtual environment before final implementation, so to get reliable predictions of the consequences (Marcucci et al 2020) for the short and long-term future (Callcut *et al.* 2021). Then, the verified measures can be applied to the real world (Hämäläinen 2021; Yang and Kim 2021). This implies visualising complex cause-effect relations, e.g., to what extent policy design principles from theory applied to the urban case in question are met by the proposed plan or project, as well as predicting and optimising urban agents' behaviour before and after a policy is implemented (Marcucci 2020).

UDTs can potentially integrate city planning and management in a single tool (Ferré-Bigorra *et al.* 2022), within one specific sector or implement a city-wide model that incorporates a multitude of systems. This may help to counteract the negative effects of fragmentation and silo-isation of urban policy (Nochta *et al.* 2019), for example identifying inconsistencies between sectorial actions and supporting interdisciplinary policy design (Nochta *et al.* 2021).

3. POLITICAL IMPLICATIONS OF URBAN DIGITAL TWINS: THE SCIENTIFIC DEBATE ON POTENTIALITIES, CONSTRAINTS AND RISKS

UDTs have been studied from different perspectives: technical (engineering-oriented), socio-technical (merging social and economic processes with the built environment and linking functional and physical processes to socio-economic representations: Batty 2018; Nochta *et al.* 2019); law and philosophy of law (issues of security, democracy and sovereignty and compliance with standards: Suffia 2022); philosophical (trying to demonstrate the ontological flexibility of plural approaches and practices of UDTs, rooted in different philosophical paradigms: Al-Sehrawy *et al.* 2023). However, empirical studies on the effects of UDTs on policymaking and urban governance and on factors on which they may depend have so far been limited, primarily because the actual use of UDTs is still in its infancy. To date, scholars have addressed both potentials for improvement of policymaking and the possible problems of UDTs, making the best of the analysis and comparison of some cases. The most cited ones are those of Herrenberg, Helsinki, Zürich and Singapore (for example: Ye *et al.* 2023).

Within these studies, we identified two main policy implications of UDTs.

First, improvement of policymaking and urban management occurs when policymakers can harness the predictive potential of UDTs, in particular the ability to forecast behaviour and reactions to policy measures implementations, providing reliable descriptions of likely scenarios (Marcucci *et al.* 2020). This allows to make more informed and faster decisions and to enable policy impact assessment, so that UDTs act as a sort of strategic planning sandboxes (Ferré-Bigorra *et al.* 2022). Using UDTs smart city practitioners can bridge multi-stakeholder urban design teams (quadruple-helix; academia–public–private–civil society) including the participation of citizens, committees, etc. This participation in the use and development of UDTs models, including the choices of data (Nochta *et al.* 2019) and digital platforms may improve the quality of public debate, as well as transparency and trust among actors. UDTs can also overcome the contracting-out of knowledge needed for policymaking from public administrations to consultants (Nochta *et al.* 2019), reducing the risk of vendor lock-in and the dominance of multinational corporations in smart city development (Hämäläinen 2021).

Second, UDT may be affected by problems and implementation gaps, which make their potential benefits unclear. These problems can be technological and logical, as well as organisational and political, especially when linking functional and physical processes to socio-economic representations (Batty 2018). For example, incorporation in the technical design of models of applied knowledge about cities and human agents produced by sociopolitical actors, as well as of social interactions, norms, regulations, culture, politics, democracy, human rights, ethics, and non-material qualities is needed to develop and use

UDTs' predictive capabilities (Nochta *et al.* 2021; Charitonidou 2022). Limits can be imposed on citizens' participation in UDTs design and use, which is highly likely to follow the top-down method of the past (Yang and Kim 2021). For all these reasons, final users should be included in UDT initiatives to gain "public acceptance" (Weil *et al.* 2023) especially in an EU in which citizens' rights to privacy are protected by the GDPR.

Several contributions have also focused on three kinds of factors that can influence how UDTs are adopted and deployed.

First, organisational cultures and issues of governance, as they unfold locally in specific cities. These aspects regard city processes, structures, and practices, the patterns of relationships between actors, which may hinder or favour multi-level collaboration and cross-sectoral integration among departments as well as local government employees' attitudes and skills (Weil *et al.* 2023: 10).

Second, the design, legitimization, and implementation of UDTs and their incorporation into local governance processes may depend on several factors. They include existing formal rules, informal regulations, and institutional logics of appropriateness (Nochta *et al.* 2019; Hämäläinen 2021) as well as the historical use and experience of urban models to support decision-making and the institutionalised roles of public, private, and third sector stakeholders (Nochta *et al.* 2019).

Third, ethical concerns such as: the risk of adopting a paradigm of "the city as a computer" instead of a living organism (Suffia 2022); the legal question of who is accountable if the UDT makes a wrong decision (Ferré-Bigorra *et al.* 2022); problems of data property and sovereignty, including threats to the privacy of individuals (Papyshev and Yarime 2021; Alva *et al.* 2022; Barresi 2023).

4. THE LOCAL POLITICS OF URBAN DIGITAL TWINS FOR SUSTAINABILITY: OUR RESEARCH APPROACH AND METHOD

Each of these factors, taken individually, may indeed prove important. However, our aim is to understand from a political sociology perspective how these and other factors can shape local politics of UDTs for urban sustainability by combining them into a comprehensive model. This model focuses on several aspects and factors emerging from the current literature and rearranges them into four analytical dimensions (frames, context, regulation, and data governance) that inform empirical analysis. Each dimension, which is based on an underlying theoretical perspective, makes it possible to provide preliminary answers to research questions:

a) *Frames*. From a perspective based on policy frames, framing processes (Rein and Schön 1994), and the role of ideas and discourses in political change in institutional contexts (Schmidt 2010), we wanted to know what cognitive and normative frames legitimise the attempts to establish algorithmic governance of cities using UDTs in policy and administrative processes and how these frames are affected by concrete social relations.
b) *Contexts*. From a perspective based on the idea that (local) "history matters" in the explanatory role of territorial and institutional contexts – the political, economic and cultural environments of cities, including path dependency on previous actions (March and Olsen 1989; Hall and Taylor 1996; Pierson 2000; Greener 2005) – we wanted to know how the local use of AI systems for sustainability may depend on factors, such as: the political and territorial environments, that is the patterns (actors and relations) of urban governance; the formal rules, informal regulations and institutional logics of appropriateness, including local government administrative organisation and culture and previous initiatives for the digitisation of urban policies.
c) *Regulation*. Taking the political and scientific debates on AI sustainability ongoing at the national, international, and supranational (EU) level and focusing on regulation, legal frameworks, rights and standards (Kuziemski and Misuraca 2020; Suffia 2022) into account, we want to know if there is room for "AI localism" (Verhulst and Sloane 2020) in the regulative context of the EU (AI Act 2023; EU GDPR 2016; EU Data Act 2023). How do actors address at local scale trade-offs between innovation and risks, i.e. pursuing AI sustainability and at the same time governing with AI?
d) *Data governance and value*. In power relations between public actors and the private and knowledge sectors data and the public interest are also at stake. From this perspective, we wanted to understand the role of these actors in pursuing a "public-centred data governance": what instruments do local administrations use to ensure public use of data? How do they deal with "the promise of using data as a resource to create value for citizens" (König 2021)? How do they balance this promise with the interests of the private companies involved as data providers and users?

We tried to answer through the comparative analysis of two UDT development projects in Italy, the DTs of Milan – *Ecosistema Digitale Urbano* – and Bologna,

Via della Conoscenza project (section 4). The comparison was based on an intensive binary research strategy (Morlino 2005, Lanzalaco Prontera 2012) in which the two cases were analysed in depth. The choice of the two independent cases (Fideli 1998) was motivated by the relevance of the projects with regard to the state of development, the scale of application (urban), the use cases[1] related to urban sustainability, and the kind of actors promoting them. The comparative analysis was conducted in two empirical phases, desk and field. The first phase was inspired by the "all is data" dictum (Glaser 2001) of the Grounded Theory approach. Heterogeneous materials on the UDT projects (press articles, institutional releases, audio-video recordings of public events, policy documents) were collected and analysed to reconstruct UDTs features (chronology; actors involved; data sources; types of technologies developed/acquired; presence of AI algorithms; use cases; policy areas; public funding sources), to trace the contexts in which the projects are embedded and to reconstruct the communicative discourse (Schmidt 2008) by which UDTs are legitimised and communicated to the general public and/or specialised circles.

In the second phase, between March and May 2024, interviews were conducted with the aim of analysing "in depth" the UDTs' policy frames, path-dependencies or discontinuities, regulatory issues, and power relations between public and private actors; pursuit of public interest. Eleven semi-structured interviews were conducted with privileged witnesses involved in the two projects[2] operationalising variables concerning the four dimensions of analysis (section 3). The texts were then analysed according to a process inspired by the "open coding" of Grounded Theory to label the most significant extracts of the interviews and open up directions of meaning (Strati 1997, Natalini 2023).

5. THE CASE STUDIES OF BOLOGNA E MILAN: DESCRIPTION

UDT projects are rapidly developing globally, in Europe and Italy. In August 2023, the *Directorate-General for Communication Networks, Content and Technology* of the European Commission surveyed 135 UDT projects in the European Union. This study classified UDTs using the categories of the DUET Digital Twin Maturity Model[3]: Awareness of Twins (political commitment verified, but no implementation); Experimental Twins (predictive scenarios based on time series); Predictive Twins (predictive scenarios based on real-time data); Intelligent Twins (AI-based self-learning capability). Most projects (49%) were classified in the Awareness category, 42% as Experimental, and none as Intelligent (DG Connect 2023). These data therefore show the nascent state of the phenomenon in Europe and the lack of advanced implementation processes.

The survey identified 12 initiatives in Italy, from which we selected the cases of Milan and Bologna. Both cases concern two Italian metropolitan cities and concern the application of DT technology to the entire urban area. The two projects are in the early stages of development, so no actual effects on policymaking and impacts on urban sustainable development can yet be observed. However, the design process, the initial stages of implementation, and the potential implications for urban sustainability can already be observed. In the following sub-sections, two summary descriptions of the two cases are provided, concerning key facts, such as: chronology, public funding lines, relation to other local policies, actors involved, types of data and technologies, and use cases (table 1). Moreover, subsection 5.3 briefly highlights the implications of UDTs for urban sustainability and the commonality between the urban policy agendas of Milan and Bologna on this issue.

5.1. Milano

The Milan UDT project was started by the local administration in 2022. The implementation phase was entirely financed (about EUR 3 million) with funds of the EU from the PON metro 2014-2020 related to the project: *Digital services to foster the economic and social development of the municipalities of the Milan Metropolitan City.*

The UDT is part of a wider local policy started by the municipal administration in 2020 (DCC No. 620, June 2020) and aimed at developing a "Digital Urban

[1] The expression 'use case' comes from computer engineering and indicates a usage scenario for a software (situations in which it may be useful) and a potential scenario in which a software receives an external request. It thus describes the interactions between users and systems. In a broad sense, 'use cases' are considered here as specific and defined areas of experimentation of a UDT for public policy purposes.

[2] Milan: 1. Board per l'Innovazione Tecnologica e Trasformazione Digitale, 2. Sistema Informativo Territoriale – Municipality of Milan, 3. Technology Officer – Municipality of Milan, 3. Technology Officer - ESRI Italia. Bologna: 1. Executive Councillor Local Government, 2. Direzione Generale Settore Innovazione Digitale e Dati – Municipality of Bologna, 3. Dipartimento cultura, sport e promozione della città, Unità intermedia cabina di regia progetto Gemello digitale – Municipality of Bologna; 4. Cineca, project coordinator; 5. FBK, project coordinator; 6. Università di Bologna, project coordinator; 7. Università di Bologna, Professor and Research Fellow.

[3] DUET Digital Twin Maturity Model: https://www.digitalurbantwins.com/digitaltwinmaturitymodel

Table 1. UDT projects in Milan and Bologna: key facts.

UDT	*Milan*	*Bologna*
Chronology	• Started in 2022 (but earlier in the Smart City policy and reporting system) • Funded with PON metro 2014-2020 (EUR 4 million) • 2023 March-April: testing of mobile mapping technology (Street Hive) by Cyclomedia • 2023: presented at Milan Digital Week on 6 October, event "The Digital Twin of the City - City Digital Twin," City of Milan	• Started in 2020 with a proposal for NRRP • 2021: municipality-University agreement • 2022: EUR 7 million PON Metro 2014-2020 grant • 2022: agreement on UDT development between University of Bologna, City Council, and CINECA • 2023: public presentation with partners • 2026: planned full operation
Broader Municipality's programme	• 'Digital Urban Ecosystem' (DUE) - DCC No. 620, June 2020	• Flagship Project "Via della Conoscenza"
Main actors involved	• Municipality of Milan • ESRI Italy - platform provider • Cyclomedia - Area Mapping • Milano Smart City Alliance's partners	• Municipality of Bologna • Alma Mater University • Bruno Kessler Foundation • CINECA • Fondazione Innovazione Urbana
Use Cases	• land-use authorization processes • compliance with land-use regulations • elimination of architectural barriers • identification of ramps and accessible paths energy containment • maintenance decision-making • irrigation control • roof cooling	• mobility (new infrastructures: Tram, Passante, Bicipolitana) • energy (response of the city's building stock, simulating the impact of including new projects in urban plans) • climate change (case study on hydrogeological instability)

Source: Authors' elaboration.

Ecosystem" (DUE), defined as: «the set of public and private digital platforms that produce data related to the city's territory, both in relation to citizens' actions and environmental conditions» (p. 26). The DUE policy is managed by the Municipality's Board for Technological Innovation and Digital Transformation, which was established in March 2022 to replace the former Department for Digital Transformation. The Board results from an organisational innovation undertaken by the local administration, acts across different administrative departments, and is directly related to the centre-left mayor's (G. Sala) policy agenda[4].

The system of actors of DUE policy has a strong public-private connotation and involves, through a memorandum of understanding, the Milano Smart City Alliance (MSCA)[5] – an initiative of the Assolombarda Foundation (territorial association of industrial firms). The MSCA involves major private players from the entrepreneurial system of Milan[6] in "smart city2 projects, providing services according to the 4 P model (public-private people partnership). These projects regard a range of urban policy areas that reflect the companies' fields of activity. The collaboration between MSCA and the City of Milan is based on the sharing on the one hand of material resources (data and projects), and on the other hand of cognitive and normative resources (the data-driven city governance paradigm) (section 7.1).

[4] Board Innovazione Tecnologica E Trasformazione Digitale: https://www.comune.milano.it/board-ited; the Board consists of: 2 members from the municipal administration, 2 academics and 9 members of the business milieu.

[5] For further information: https://milanosmartcity.it

[6] Partners of MSCA: A2A Smart City, Accenture, ATM, Cisco, Coima, Dassault Systèmes, Enel X, Fastweb, IBM, Siemens, Signify, TIM e Assolombarda.

Data providers of DUE are the municipality and other public bodies that carry out activities on the municipal territory, companies, citizens and city users, freelancers, Civic Hackers – citizens involved in participatory practices and third sector associations (Ibidem: 26-27). On the one hand, the DUE is expected to act as a "data provider" to the UDT; on the other hand, the UDT will be the tool to manage, process, and thus "capitalise" data for the purposes of the public administration, citizens and businesses. Therefore, the development of a UDT needs the interoperability of public and private data, which should be made possible by software such as the Application Programming Interface (APIs).

In 2023, the company Cyclomedia carried out an "Area Mapping" activity to integrate and update 22 cartographic databases of the municipal administration, a spatial data asset on which the DT platform will be based. These data are hosted in the ArcGIS platform owned by ESRI Italy, a Netherland-based multinational company, and technological partner of the Sistema Informativo Territoriale – Municipality of Milan. This platform allows «to integrate information, systems, models and flows in a spatial context, creating a holistic representation of environments, assets, networks and data in the city»[7]. Therefore, the DT of Milan is an evolution of the preexisting GIS platform that, through AI technologies, will be able to create detailed and realistic urban models that simulate the behaviour and development of the urban environment over time.

5.2. Bologna

The idea of a DT of the city of Bologna dates to 2020, during the application phase of local government projects to the National Recovery and Resilience Plan (NRRP). The UDT is part of the "Città della conoscenza" (Knowledge City), a flagship project of the municipal administration and of the political mandate of the centre-left Mayor M. Lepore. It represents «the main instrument of the city's new digital strategy, a real hinge between the different dimensions of policies related to digital transition and Big Data, […] which will act as an interface and platform for public data sharing on health, climate, environment, mobility» (Comune di Bologna 2022: 36). The "Città della conoscenza" and "Impronta Verde" flagship projects, "Missione Clima", "Piano per l'Abitare" policies are considered tools for realizing an inspiring vision that aims to make Bologna the "most progressive city in Italy" (Comune di Bologna 2023).

In the autumn of 2023, the local government presented the UDT project to the public and started its implementation based on a EUR 7 million PON Metro grant. The Bologna UDT is designed and developed by a consortium of public actors that shapes an ecosystem with a strong public-public connotation. This ecosystem was established through several agreements between the municipality and its partners that is going to last until the end of the administration's political term.

This public ecosystem involves the following actors, each one with its own role and task: Municipality of Bologna, promoter of the project and strategic coordinator, decision-maker in the choice of use cases and user; Fondazione Bruno Kessler (FBK)[8], technical coordinator and project manager, supplier of the data platform, co-leader in national policies about UDTs (section 5.2); Alma Mater University of Bologna, scientific manager and leader of research activities on ethics, legal and data management issues; Cineca[9], technology manager, provider of calculation systems, deals with the processing of use cases; Fondazione Innovazione Urbana (FIU)[10] community manager, responsible for future citizen involvement actions.

The UDT project is based on the systematisation of a large set of data already in the possession of local administrations and consultable by citizens (Portal Opendata, Territorial System SiT - Metropolitan City of Bologna, Portal Invento - Infrastructure Cadastre) and of an already widespread digital sensor system, e.g. in the mobility sector. These databases will be integrated with the data assets of the ecosystem partners, particularly the University of Bologna. Furthermore, according to the interviewees, data integration will be conducted through a 'concentric circle model': data from the local administration and partners, public-owned utilities and, finally, also private companies.

The mayor and the executive councillor in charge of the project have often emphasised the UDT as an ambitious goal of the city government, which can be summarised as decision support based on advanced data processing and AI technologies, predictive scenario formulation, and unprecedented statistical inferences.

[7] ESRI Italia, *Il Comune di Milano presenta il progetto del Digital Twin*: https://www.esriitalia.it/case-history/pubblica-amministrazione/920-il-digital-twin-del-comune-di-milano-per-la-smart-city

[8] The Foundation is a private law body under public control (Autonomous Province of Trento).

[9] Cineca is a non-profit Inter-University Consortium with full public participation, for further information: https://www.cineca.it/en

[10] Centre established in 2017 by the Municipality of Bologna and the University of Bologna: http://www.fondazioneinnovazioneurbana.it).

5.3. UDTs for urban sustainability: use cases in Milan and Bologna

The survey conducted by the European Commission identified the main use case domains of UDTs[11] (DG Connect 2023). These domains have direct and indirect implications for the field of urban sustainability. Primarily, 41 projects are designed to mitigate environmental impacts and promote urban resilience practices. Secondly, most projects aim to improve the management of natural resources (e.g. water management), energy consumption, and traffic flows, which is one of the main sources of pollution in urban areas. As argued by DG Connect: «cities and communities can use DT to optimise energy consumption and achieve greater resource efficiency. LDTs can be essential tools towards sustainable urban planning decisions and operational maintenance that minimises the use of resources by predicting future needs […] it can contribute to the monitoring of communities' environmental footprint» (*Ibidem:* 69).

The differences between the UDT projects in Milan and Bologna will be commented on in the following sections. Basically, they share use cases with important implications for urban sustainability. On the one hand, the Milan UDT aims to improve the delivery of public and private services to citizens, as well as land management policies and urban planning. On the other hand, the first use cases concern policies and decisions in the field of environmental and social sustainability (e.g. curbing energy consumption; cooling buildings through green roof solutions; eliminating architectural barriers). In Bologna, the UDT can be applied to decision-making in several policy areas. The first use cases concern the mobility sector – the management of traffic lights – and environmental policies aimed at reducing the energy consumption of the City's building stock.

More generally and independently of UDTs the political agendas of Milan and Bologna administrations share a strong focus on urban sustainability, as evidenced by several policies, particularly in urban mobility, participation in transnational networks of cities and involvement in the implementation of EU Green New Deal. For example, Milan was one of the first Italian metropolitan areas to introduce a congestion charge in 2012 (initially called "Ecopass"), and Bologna has implemented a significant intervention on private mobility (Bologna Città 30) in 2023, which includes stricter speed limits, the creation of new pedestrian and green areas, and new bicycle lanes. Milan is also one of the leading cities in the C-40 network on climate change policies, one of the promoters of the Milan Urban Food Policy Pact on the sustainability of food systems and, together with Bologna, one of the 112 cities involved in the European Commission's "Climate Neutral and Smart Cities by 2030" initiative[12]. In this regard, in 2022 the new Mayor of Bologna M. Lepore inaugurated the flagship project "Missione Clima", a complex intervention to achieve climate neutrality strongly based on citizen participation[13] and the instrument of the "Climate City Contract" that defines commitments and priorities of the administration, actions and investments.

Thus, the UDT projects of Milan and Bologna fit into the established sustainability agendas of their respective local administrations. Although it is too early to assess its impact, the DT technology adds a new tool to the "twin transition" undertaken by the two cities, although through two different implementation models, as shown in the next sections.

6. RESEARCH FINDINGS: FRAMES, CONTEXTS, REGULATION AND DATA GOVERNANCE

The comparison of the two cases through our four analytical dimensions allowed us to identify common features and differences in the way the UDT technological tool has been incorporated into the policies and governance of Bologna and Milan (Table 2).

6.1. Frames

In both Milan and Bologna, the political legitimacy of UDTs – that did not cause political contention in the city councils – is provided on the one hand by the policy paradigm of urban sustainability and, on the other hand, by the increasing worldwide diffusion of expectations and trust in technical tools such as AI and DTs to address sustainability challenges. However, this paradigm is subject to different declinations. In Bologna, it is presented as a democratic and progressive green and digital transition, based on the connection

[11] In order of occurrence: Urban planning and infrastructure; Urban mobility and traffic systems; Environmental management, sustainability, and resilience; Energy management; Community Engagement; Urban logistics; Water management.

[12] The initiative, which is part of the implementation of the European Union's Green Deal, aims to deliver 100 climate-neutral and smart cities by 2030 and ensure that these cities act as experimentation and innovation hubs to enable all European cities to follow suit by 2050.

[13] In 2022, the first Climate City Assembly was established involving randomly drawn citizens involved in deliberative processes on the climate policies of the city administration. More information is available at link: https://www.comune.bologna.it/partecipa/percorsi/assemblea-cittadina-per-il-clima

Table 2. Two patterns of local politics of UDTs.

Milano	*Analytical dimension*	*Bologna*
Data-Driven City Private-driven innovation	Frames	Knowledge City Innovation through public autonomy
Organisational change Network: public-private Multi-scalarity by firms	Context	Organisational continuity Network: public-public Intergovernmental multi-scalarity
Defensive compliance	Regulation	Invention of soft-law tools
Public and market oriented	Data governance and value	Public oriented

Source: authors' elaboration.

between urban sustainability, digital transition, and the "City of Knowledge" development strategy. In Milan, more emphasis is placed on the economic dimension of urban dynamics and policies, prioritising efficiency and innovation in service delivery in a "Government as a Platform" perspective (Cordella and Paletti 2019). These goals can be achieved by a "data-driven city"[14] (interviews), defined by M. Flowers (2013: 186) «a city that intelligently uses data to better deliver critical services. […] smarter, risk-based resource allocation, better sharing of information agency-to-agency to facilitate smart decision-making, and using the data in a way that integrates in the established day-to-day patterns of city agency front line workers. Being data-driven is not a primarily challenge of technology; it is a challenge of direction and organisational leadership».

This differentiation can be explained by considering the respective systems of action of the UDTs. Although both are led by their respective municipalities, in Bologna the idea originated in academia and the FIU and has so far only been developed by public (local and national) actors, without the involvement of private firms. This choice is also motivated by the intention to ensure political control over the UDT's technologies and processes and to avoid lock-in situations with privately owned data (interview). The legacy of the Smart City paradigm and actions concerns the physical infrastructure (e.g. IoT sensors) and the public data assets that feed the UDT. In Milan, on the contrary, the idea of UDT is exogenous to the public sector and comes from lessons learnt from the private sector, especially from technology service provider partners. The corresponding system of action builds on and further consolidates the network and system of values and goals of the pre-existing MSCA. Companies play a key role in the whole process: they provide knowledge and AI systems (the platform of the UDT, an evolution of the geoportal, provided by the same private partner), they collect and enter urban geospatial data, and they too can benefit from the processed data. Furthermore, they bring networking and legitimisation resources into the UDT project, playing an important role in communication processes where practices and use cases are shared and in events promoted by the Municipality, such as the Milano Digital Week[15], and other events aimed at increasing the urban attractiveness for technology companies.

6.2. Context

In both cases, the UDT is realised within systems of pre-existing relationships, public-private in Milan and public-public in Bologna, in which few elements of discontinuity are introduced. Also, for this reason, the project management induced fewer organisational changes for the public administration of Bologna. The management is entrusted to two pre-existing organisational units of the municipality, with the technical external coordination of FBK (an element of discontinuity), which was established by public actors and specialises in AI. The organisational articulation is multi-scalar: local; regional (the Emilia-Romagna 'data valley' policy and its Technopole); national (the role of the UDT in spoke 9-Digital Society and Smart City, National Research Centre in High Performance Computing, Big Data and Quantum Computing), funded with NRRP-NGEU funds. The solutions for the overall co-ordination of the UDT project are based on the habit of these actors of working together. This is the product of the consolidated cooperation between the Municipality, the Univer-

[14] Il progetto Data-Driven City di MSCA: https://milanosmartcity.it/projects

[15] Milan Digital Week edition 2023: https://www.milanodigitalweek.com/index.html

sity, FIU, and Cineca, which allows for public autonomy with regard to the cognitive and technological resources needed, while the "local political entrepreneurs" of the UDT project - Mayor M. Lepore and the councillor in charge of the UDT program provide political leadership and legitimacy.

In Bologna the involvement of private companies (a fabric of mostly local SMEs) is envisaged (interviews) only at later stages of the UDT project's implementation. In Milan business actors (with the presence of innovative big firms) are included in the decision-making processes through formal (the memoranda of understanding between the Municipality and MSCA companies) as well as informal (events such as Milano Digital Week or the ESRI Italy Conferences[16]) and organisational instruments. In the city administration, the Board for Technological Innovation and Digital Transformation serves, on the one hand, to promote coordination between sectoral organisations of the municipality and overcome the silo effect in digital innovation policies and actions. On the other hand, the Board helps to institutionalise the leading role of knowledge and private actors, who are directly involved in the city government. So, the board gets political legitimacy from its direct relationship with the mayor but is also a privileged venue for the public-private partnership. Resources and data are made available to all partners, who benefit from them for public policy on the one hand, and for business strategies on the other. In this way, the UDT project becomes one of the pillars of a wider DUE (see section 5.1), developed by the local government and MSCA players. A problem concerning the autonomy of public actors is not perceived by those involved in the UDT project in Milan, since the goal is to promote an open infrastructure to create public and private value (interviews). Unlike in Bologna, an extra-local articulation of the UDT action system is provided by the spatial and scalar extension of the private companies involved in the UDT project as providers of technologies, which may facilitate the establishment of networks of cities that employ the same proprietary technologies and exchange their experiences on DTs.

6.3. Regulation

UDTs in Bologna and Milan and the AI models and systems they use are facing some of the same ethical and legal problems, which are the subject of regulatory efforts almost all over the world. Moreover, the two UDT projects share the same regulatory context of digital technologies and their use for public purposes, consisting of national and, above all, EU highly articulated systems of legal norms and standards. Their existence reduces and simplifies local actors' challenges of governing technological innovation while governing through technology, as the problems are largely limited to compliance with superordinate norms. On the other hand, this same regulatory system introduces constraints for local actions. In other words, there is no considerable room for an 'AI localism' (Verhulst Sloane 2020) such as that characterising local AI experiences where institutional arrangements leave more autonomy to subnational decisions, as it happens in the USA. In Bologna, the university is drafting guidelines (a kind of soft law) to adapt compliance with European standards to the specific data management and uses of the UDT, which are still partly to be specified, and to establish a "civic guarantor" and an "ethics committee" for the UDT. It is to be expected that such proposals may find their own space for experimentation within the 'regulatory sandboxes' of the EU AI Act (Art. 57). In Milan, attention was paid to compliance with current privacy regulations (in particular the GDPR) when collecting images to train the UDT.

6.4 Data governance and value

The issue of how to govern the data used for UDTs has been addressed differently in Bologna and Milan, in a manner consistent with how consolidated public-public and public-private coalitions structure the aims, forms of coordination and organisational cultures of urban governance in the respective urban settings.

Public governance of data to create public and citizen value (König 2021) is a priority of the Bologna UDT project. Consistent with this priority is the intention to develop accountability and involvement tools aimed at citizens (although still to be implemented). If data assets are public and protected from interference by private interests (as providers of both data and technology), their use must be co-decided between political authorities and citizens. The latter will not only be able to evaluate the decisions resulting from the UDT elaborations but also to express themselves on its use. The planned behavioural change and nudging interventions based on the UDT will also have to be supplemented with citizen engagement tools (interviews). To design the tools of participation, it is planned to make use of the "citizen science" expertise of the university and FIU.

In Milan, data governance is public-private and the issue of citizens' participation is more blurred. They will be able to benefit from the knowledge provided by the

[16] The Esri Italy Conference 2024: https://www.esriitalia.it/news-ed-eventi/eventi/conferenza-esri-italia

UDT and use the services based on it, but they cannot take part in its design and decisions on its implementation. The public value of data is interpreted in a market exchange logic: the UDT will enable innovative services for citizens and city users. In return, citizens can generate value by making their data available to the UDT platform. The public value of data benefits all policy-takers through the possibility of basing city government decisions on objective data and knowledge (data-driven city).

7. DISCUSSION AND CONCLUSION: TWO PATTERNS IN THE LOCAL POLITICS OF URBAN DIGITAL TWINS

Our comparison made it possible to draw some conclusions about the political implications of UDTs' uses in processes of urban policy and governance aimed at sustainability. We have seen that local agency leads to different approaches and, potentially, different outcomes. This emerges from the analysis of design (platforms, data, uses, rules) and early implementation activities of UDTs and confirms that relations between digital/AI technologies and the political, administrative, economic, and cultural environment of cities affect the local use of AI systems (Nochta *et al.* 2019).

What provides local actors with room for manoeuvre in these two cases of UDTs? First, the diversity and plasticity of UDT models, systems, and purposes (sections 2, 3). Second, the two main global sources of political legitimation of the UDT. On the one hand, the paradigm of sustainable urban development confirms its elasticity and adaptability to different spatial contexts and policy goals. On the other hand, there is a growing global expectation and trust in multi-purpose digital instrumentation, including AI and UDTs, to address sustainability challenges. Combined, they compose a significant part of the mainstream metaframe of contemporary urban policies. In both cities the political leadership favours an alignment to this metaframe, but the differences we have noted shed light on two different hybridisations that, to some extent, reflect the variegation of neoliberal urban governance (González *et. al.* 2018) and produce two patterns of local politics of UDTs:

(i) in Milan, the "data-driven city" imaginary that synthesises the political meaning of the UDT is closer to an idea of algorithmic governance of urban sustainability and coherent with a private-driven innovation and a public and market-oriented value of data;

(ii) in the vision prevailing in Bologna different dimensions of the uses of technology for sustainability seem to be kept in balance by the "Knowledge City" imaginary, which gives more power to citizens and knowledge actors and less to market actors to make choices concerning such uses and their control, as well as more importance to the public value of data, limiting the access of business to the design, control and use of UDT and its algorithms.

On what do these different ways of exploiting the margins of place adaptation of paradigms and technology through the local politics of UDTs depend? We have tried to answer this question through the lenses of frames, contexts, regulation, data governance, and value (sections 4, 6). The most important factor that contributes to differentiating these aspects and producing two patterns of local politics of UDTs consists of the relationships between politics and society in urban governance. More specifically, this regards the different economic characteristics of private interests, their capacity for cultural influence within urban systems, and the intensity and forms of their involvement in governance processes. These factors influence the different composition of the UDT action systems in the two cities. Corresponding to this composition are the logics of appropriateness underlying common action, which have similar degrees of institutionalisation, but are different from each other in terms of values and beliefs.

In Bologna they make evident an attempt to assert the pre-eminence of politically legitimised actors in defining the purpose and control of urban resources and, therefore, also of technologies and algorithms. Although at a later stage of UTD development local private interests are also supposed to benefit from this technological infrastructure, they will not have established its operation. Moreover, the expected role of citizens in the future use of the UDT reproduces two pillars of the "Bologna Model" (Massari and Orioli 2023): a diffuse and horizontal vision of the powers of the administration in a paradigmatic context for social capital and civic engagement; an approach to the planning and development of the city based on the strategic vision of the interests of the community. Also in Milan, the sense itself of technological innovation in urban policies derives from the encounter between the mainstream policy paradigm mentioned above and the system of values and beliefs the local pattern of governance and urban political economy is based on, which is based on the involvement of private actors and consequently more inspired by market values and beliefs (d'Albergo *et al.* 2022; Andreotti and Le Galès 2019). In each of the two cities, this transfer of logics of action, practices, and forms of coordination from the broader systems of relations between local politics and urban society to the more circumscribed systems of action of the respective UDTs is mediated by the pathways realised in the field of digital innovations in urban

policies and governance, primarily with the configurations assumed by Smart City experiences.

As we have seen, the implementation of UDTs in the two cities is still taking its first steps. On the one hand, contextual factors, such as the foreseeable rapid technological transformations and further developments in European and national AI strategies and regulations, and on the other hand, the learning that will be made possible for local actors from the implementation of the projects, will offer the possibility to monitor continuities and transformations in the local politics of UDTs.

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