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Urban futures in the mirror of technology? The politics of urban digital twins

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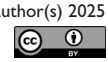

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Abstract

Urban digital twins (UDTs) represent a growing trend in urban governance, offering the promise of enhanced prediction, decision-making, and public participation. Adopting a constructivist perspective toward UDTs, this article contributes to the emerging literature on "twinning": the making of UDTs, which produces an interrelation between tangible reality and its digital representation in order to enable new forms of knowledge and urban governance. Through a comparative analysis of UDT projects in Boston, Namur, and Munich, we explore how digital representations of cities are co-produced with ideas about desirable governance. Our locally situated perspective highlights the interrelations of twinning in three dimensions: representation, epistemic promise, and ideas of desirable urban governance. The analysis provides crucial insights into the role of digital technologies in shaping urban futures, offering a critical reading of the current trend of UDTs in urban governance, and is attentive to its social and political implications.

Keywords

Datafication, digital twin, twinning, urban digital twin, urban governance

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Introduction

Originating in the manufacturing industry, the term "digital twin" broadly refers to a virtual replication of a physical entity that is connected in real time through a bidirectional flow of data and information. Recently, this concept has been applied to various contexts, including the urban sector and city administration.

In its simplest form, an "urban digital twin" (UDT)[1] refers to a digital representation of the city. Many conceptualizations of UDTs suggest a detailed, interactive, real-time virtual model of the city that represents and analyzes its real-world counterpart. They promise a range of benefits such as more efficient and sustainable resource use, better decision-making through comprehensive data, acting as virtual testbeds for future scenarios, and enabling city managers and stakeholders to simulate, model, and analyze the impacts of different actions on the urban environment. Considering visual imagery as a powerful tool, UDTs are also often presented as supporting democratic participation by using advanced 2D and 3D visualization interfaces to involve stakeholders and citizens in urban governance (Dembski et al., 2019). The ideas behind the current promotion of UDTs in urban governance align with many ambitions of the smart city discourse, such as using digital technologies for the economic and environmental performance of cities while creating a better quality of life for residents (Karvonen et al., 2020).

Against this backdrop, scientists have already begun to take a critical look at the UDT concept, and earlier work on smart cities and the datafication of society offers potential starting points for a reflexive examination of this emerging phenomenon. Common concerns regarding the pervasive employment of digital technology in the urban space include issues of privacy, surveillance, accuracy, and representativeness of data, as well as the potential for reinforcing existing power imbalances (Kitchin, 2014; Morozov and Bria, 2018). Discussions about digital representation and ethical implications of data practices urge us to interrogate the ways of knowing that are inscribed in ever-expanding digital technologies (Galloway, 2021; Vertesi, 2016). Gabrys (2019), for instance, engages with the politics of cities becoming "sense-able" through the formation of novel human and more-than-human entities.

To understand UDTs primarily through a lens of data practices and the politics of quantification, driven by the promises of real-time tracking and predictive analytics, is to risk neglecting how UDT projects shape and are shaped by the practices of urban planning and governance more broadly. To understand the mutual influence of UDT projects and conceptions and practices of governance, this article locates UDTs in the context of urban governance and related aspects such as policy tools, planning models, and participatory processes, shifting attention to UDTs in the making and the process of "twinning" through which digital replications of cities are created (Solman et al., 2022). We specifically ask how UDTs take shape and evolve together with governance approaches in specific urban contexts, elaborating on how processes of twinning are situated at the intersection between (1) UDTs as specific technologies of urban governance and (2) ideas of what desirable governance could look like. Sadowski and Bendor (2019) argue with regard to smart city narratives that "future research must resist the temptation to assume that the smart city will work or be materialized in exactly the way the corporate imaginary lays out" (p. 556). A similar point

applies to the emergence of UDTs, prompting us to examine how they actually materialize on the ground beyond ideal-typical definitions and the promises of ubiquitous datafication—expectations that actual UDT projects rarely achieve or even attempt (Fraunhofer, 2021).

To gain a localized understanding of the governance practices associated with the notion of twinning, we conduct three case studies, examining the implementation of UDTs in the cities of Boston (the United States), Namur (Belgium), and Munich (Germany).[2] These case studies primarily utilize semi-structured interviews and document analysis, as well as news media articles, public statements, and websites as supplementary information. Through a comparative analysis, we explore how these UDTs emerge as tools for urban governance, investigating their evolution alongside specific governance approaches in each city. Our focus is on how these tools reflect and reinforce particular visions of desirable urban governance, while also opening up new possibilities. Specifically, we address the intricate interplay between technology, knowledge, and urban governance, as well as between the real world and its digital replication, through three analytical dimensions: the representation of the city as part of the UDTs, the epistemic hopes and promises associated with the creation of UDTs, and the actors' conceptions of desirable urban governance. Our findings highlight that the design and implementation of UDTs are deeply intertwined with local governance priorities, shaping and being shaped by the specific urban contexts in which they are embedded. Furthermore, we show how UDTs, while enabling novel forms of knowledge and participation, also carry the potential to reproduce existing power dynamics and inequalities within urban governance.

Through our analysis, we argue for a broader perspective on twinning—not merely as the linear process of creating a circumscribed, material representation of a city, but as the complex interplay of material, social, and political relations. By focusing on the making of UDTs at the local level—beyond the global circulation of standardized models which is often the focus in public discourse—this article highlights how the shift toward digital representations in urban governance introduces new dynamics while maintaining connections with historical practices; how UDTs both reinforce and transform established governance mechanisms. We thus offer a critical reading of the current trend of UDTs in urban governance, attentive to its social and political implications.

A co-productionist perspective on UDTs

The trend to address grand societal challenges such as urbanization, densification, and climate change through novel technology (Karvonen et al., 2020) has recently gained worldwide visibility with the publication of smart city agendas (Coletta et al., 2018), in which urban spaces are presented as experimental "testing grounds" (Halpern et al., 2013; Karvonen and Van Heur, 2014; Laurent and Pontille, 2018). The literature has contextualized UDTs as being enabled by smart cities and the data and resources they provide (e.g., White et al., 2021) or as enablers of smart cities themselves (Nochta et al., 2021). A study by Nochta et al. (2021), for instance, set out to demonstrate how "a two-pronged strategy combining social (urban governance) and technical (data and modeling) insights can

support the conceptualization, design, and implementation of data-driven solutions and digital tools within the broader urban 'smartification' agenda" (p. 263).

Accordingly, UDTs have been framed as an emerging tool in urban governance and can be read as a continuation of government efforts to tackle urban challenges with data-driven approaches—a "steering technique" that "based on information analysis [. . .] steers a physical entity towards a particular goal" (Korenhof et al., 2021: 15). This aligns with Karvonen's (2020) observation of a "palpable enthusiasm to increase urban knowledge through the application of big data, ubiquitous sensing, geospatial and social network analyses, algorithms, machine learning, and artificial intelligence" (p. 418), directing attention to the entanglement of smart, data-driven knowledge-making with urban governance and planning. The role of data-driven governance approaches ranges from potential models, analytics and data that administrations and policymakers rely on for decision-making and public management, to moments where governance is executed through automated and cybernetic systems, sometimes described as "algorhythmic" (Coletta and Kitchin, 2017).

In this way, UDTs can be understood as a continuation of datafication—"the transformation of social action into online quantified data, thus allowing for real-time tracking and predictive analysis" (Van Dijck, 2014: 198). However, framing UDTs primarily through a lens focused on data practices and the politics of quantification risks reducing the analysis to a narrow view of urban spaces solely as quantifiable data streams for governance purposes. We seek to widen this perspective by highlighting the making of UDTs as embedded in broader, established mechanisms, such as urban planning, physical and conceptual models, and participatory consultation processes that utilize material, discursive, or numerical representations of the city.

To do so, a useful resource to start with is the notion of data assemblage—"complex socio-technical systems infused with politics and context" (Kitchin et al., 2015: 7). This notion emphasizes that the generation, circulation, and deployment of data are constituted and framed by a set of technological, political, social, and economic elements (Kitchin and Lauriault, 2014). Assemblages include "systems of thought, forms of knowledge, finance, political economy, governmentalities, and legalities, materialities and infrastructures, practices, organisations and institutions, subjectivities and communities, and (market-)places" (Hepp et al., 2022: 5). This perspective points to the heterogeneity of potential implications and shows that understanding UDTs can benefit from conceptualizing them as more than a purely technical phenomenon. However, it remains an open question how UDTs come about as such systems and how the relationship between technology, knowledge, and power is shaped in light of the material affordances, visions, and decisions that go into the making of a UDT and the making of governance.

To grasp this interplay in the process of twinning, the idiom of co-production, which posits that "the ways in which we know and represent the world (both nature and society) are inseparable from the ways in which we choose to live in it" (Jasanoff, 2004: 2), offers a valuable analytical framework. From a co-productionist perspective, we conceptualize the phenomenon of UDTs not as a set of self-evident technologies; what counts as relevant data depends on prior normative choices regarding what is worth recording, who is best positioned to collect and report data, and what forms of analysis and representation are taken to be compelling (Jasanoff, 2017). Our perspective

therefore complements recent studies that emphasize that a UDT will always remain an incomplete representation of the physical entity it is supposed to represent, highlighting their context-sensitivity (Nochta et al., 2021).

Korenhof et al. (2021) argue that the steering capacity of digital twins is "underpinned by normative framing and instances of inclusion and exclusion on several levels" (p. 18). According to Westerlaken (2024), digital twins are reductionist and reinforce existing power structures. Solman et al. (2022) state that the act of twinning itself—described as "a set of active design processes that hold consequences for how wind energy is designed and managed" (p. 272)—is inherently a process of governance by design. Nochta et al. (2019) argued that decisions about UDTs should always be sensitive to the specific context in which a UDT is created.

These arguments highlight not only the making of digital twins but also put the metaphorical idea of a "twin" and related terms such as "mirror" into a critical perspective (see, for example, Batty, 2018; Tomko and Winter, 2019). Rather than engaging directly in this definitional debate, this article leverages the ambiguity of the concept to investigate why urban projects are framed as digital twins and to explore the performative dimensions—affordances, imaginative power, and future-making capabilities—of this label.

Rather than understanding digital twins as simply "mirroring" reality, a co-productionist perspective suggests that in the process of twinning certain elements are included in or excluded from a digital representation, depending on choices made by social actors and shaped by broader conceptions of what a "good" UDT is, what purposes it serves, and how it is supposed to improve urban governance. This inquiry is crucial as the twinning process, especially when transitioning from material and social representations to digital ones, reveals continuities with historical practices while also introducing new dynamics (Shelton et al., 2015).

Based on this premise, a co-productionist lens specifically directs attention to local contexts. Medina's (2011) seminal book illustrates how socialism in Allende's Chile emerged hand in hand with cybernetic approaches to managing the state. The author shows how it was a specific articulation of cybernetics and a specific idea of democratic socialism that enabled these elements to develop in concert. Similarly, work on regional innovation cultures has highlighted how "regional innovation initiatives and technology developments [...] are being brought into alignment with local identity, socio-economic legacies, and unique political cultures" (Pfotenhauer et al., 2023: 2; see also Macq, 2021), showing how abstract concepts—such as the idea of a UDT—are shaped to fit local contexts.

This analytical perspective explores the factors and dynamics involved in the twinning process and the creation of UDTs. It raises questions about how UDTs—now a global trend adopted by cities of all sizes and promoted by software companies offering ready-made solutions—are localized and adapted by urban administrations. We explore and compare the UDT projects of Boston, Namur, and Munich, asking how UDTs take shape and evolve together with governance approaches in specific urban contexts. Specifically, we examine how promises and notions of desirable urban governance are inscribed in UDTs, and how these, in turn, enable new visions and approaches to governance.

Research approach and empirical material

Our research follows a qualitative, interpretative, and pragmatic approach based on grounded theory (Charmaz, 2006). Previous analyses working with the co-productionist idiom have emphasized the value of comparative methods for revealing local specificities (Jasanoff, 2007). We conducted a comparative analysis of different cities' UDT projects to explore how they are taking shape at the local level and what we can learn from this for the ways in which ideas of desirable urban governance and technologies deployed for this purpose are related.

A main criterion for the selection of cities was the existence of a UDT project driven by public authority, i.e. by the city government and/or administration. We selected Boston, Namur, and Munich because all three cities recently initiated UDT projects. While belonging to democratic, industrialized countries, these cities have distinct local political systems that are "different enough to present interesting contrasts" (Jasanoff, 2007: 29).

We collected our data mainly through semi-structured interviews in Boston, Namur, and Munich, as well as document analysis. We approached relevant interview participants by identifying actors involved with the local UDT projects, including employees in the public sector, but also several private sector representatives and experts of the broader field. The interviews for Boston (5 interviewees) were conducted between September 2022 and March 2024. The interviews for Namur (6 interviewees) were conducted between November 2022 and April 2023. The interviews for Munich (8 interviewees) were conducted between March 2023 and March 2024. All names and affiliations were anonymized to ensure confidentiality. Rather than providing an exhaustive account of each city's UDT project, we selectively cite interview excerpts that best represent key findings across cases. As the interviews were conducted with individuals, the content reflects their personal views.

We first approached our empirical material through inductive analysis. As we progressed, we identified relevant categories for the comparison of the three cities based on emerging and recurring themes, which will be further explained below. We systematically coded our data, looking for patterns and connections that highlighted both the unique and shared aspects of the UDT projects in Boston, Namur, and Munich. This iterative process involved constant comparison, where we continuously refined our categories and themes to ensure they accurately captured the nuances of each city's approach to UDT projects. By triangulating our findings with supplementary information such as news media articles, public statements, and websites, we developed a comprehensive understanding of how UDTs function as governance tools while remaining attentive to the local specificities that shape their application.

This comparative, co-productionist analysis provided insights into the contextual factors influencing the design and implementation of UDTs, and how these factors shape their impact on urban governance. Throughout the analysis, co-production is treated as an analytical approach to understand the socio-technical configurations of UDT projects. Instead of merely highlighting the diversity of actors involved across sites, we utilize

co-production as a lens to interrogate the distribution of agency, the emergent power dynamics, and the contested processes of technological design and governance. Such an approach provides critical insight into how notions of participation and collaboration are both operationalized and challenged within UDT initiatives.

The UDTs of Boston, Namur and Munich

Boston: analyzing shadow impacts in the development review process

In Boston, the UDT is synonymous with the 3D model of the city, also called the "smart model," which is maintained by the GIS team of the Planning Department, formerly the Boston Planning and Development Agency (BPDA).[3] As one administration worker (November 2022a) noted, "When people say digital twin [...] how is this different from just saying a 3D model, a citywide 3D model." Boston has worked with digital 3D models for more than 20 years and the smart GIS-based 3D model for at least 10 years. Only within the last 5-8 years has this model become associated with the concept of a UDT. The BPDA started working on digital 3D models of development projects around the year 2000 as a tool to understand new developments in context. Now, Boston's 3D models are appreciated by developers and the BPDA, academics, and for constructive public dialogue, as stated on the website.[4]

While it was at first difficult to get the project off the ground, the 3D model received a push through a controversial building proposal, Winthrop Square (Patrick, 2018). The development proposal, among other things, would have cast more shadow on the Boston Common Park in Downtown Boston than legally permitted and impacted flight routes to Boston Logan Airport. The need to protect the park justified the need for shadow and visibility analyses, positioning the 3D model as an effective tool for this purpose. The BDPA created the "shadow study" in cooperation with the globally operating software firm ESRI, which had been a partner since, and so has an external consultant to the project. During the time of data collection, a rather small group of people seemed to be working on the 3D model. As one interviewee mentioned, they are "starting small" and trying to "build trust" with it within the administration by demonstrating the UDT's utility and value to other agency members (administration worker, November 2022b).

Namur: raising public awareness for sustainability

"Namur 3D" is a 3D model of the city of Namur, the administrative capital of Wallonia (Belgium). It is publicly accessible via a web platform,[5] where users begin on a map of the city that features a default view of the Town Hall, with every built volume in the city modeled in 3D. The web visualization platform is also integrated into "Namur Smart and Sustainable" (NSS), a physical space seeking to put citizens at the heart of the debate on the future of Namur and questioning "the role of cities in the face of current and future challenges."[6]

In creating this tool, the Namur city government sought a way to address a perceived deficit in public awareness of sustainability issues. The origins of Namur 3D lie in the will

and influence of the former municipal minister for regional planning, urban development and energy (Ecologist Party, in office from 2006 to 2018). He developed several important projects for regional planning and urban development, linked to the ambition of tackling climate change at the urban level by turning Namur into an ecologically sustainable city. To achieve this goal, the minister and his cabinet developed policies to reduce energy consumption in the city, notably by improving the energy efficiency of private homes. Motivated by his pedagogical background, he reflected, "How can we reach everyone? How do you raise awareness? How do you visualize such abstract things as insulation etc.? I am a teacher by training, I am obsessed with pedagogy" (minister, April 2023). Building a 3D model of the city appeared as a solution, imagined as a means to raise public awareness and develop better knowledge of the city for urban planners. Yet, several actors in the city services noted that Namur 3D did not live up to the original expectations: no more data were included in the model beyond its initial development, and its use in terms of urban planning remained marginal. Besides being publicly accessible, members of the urban planning department currently only use the tool occasionally as a consultative device with no constraining force to check certain elements as part of building permit compliance investigations. So far, the model has not been developed into a broader planning or decision-making tool nor integrated across administrative services.

Munich: developing a platform as the digital heart of the future city

Munich understands its digital twin as "the digital heart of future city Munich," according to statements on its official website.[7] It is being developed in cooperation amongst Munich's Geodata Service, the IT department, the municipal departments, and external partners such as the Technical University of Munich and several private sector actors. While acknowledging that the 3D model is an important component of a digital twin, Munich envisions its UDT not as a singular model but as an interconnected concept that integrates the city's digital resources.

The development of Munich's digital twin began in 2018, emerging from other smart city projects. Based on their experience in various projects, the initiators came to the conclusion that a digital representation was necessary to make better use of urban data and to provide a better basis for decision-making. As one interviewee realized at the time, "we actually need a digital image of the city, but we don't have one. This idea: you have to network things together and not just map them digitally, in 3D" (administration worker, September 2023). A small group of people in the city administration led the effort to get the UDT off the ground. Since then, it has been supported by several third-party funded projects, for example, with 10 million euros in project volume as part of the federal "Clean Air 2017 to 2020" immediate action program, embedded in the overall goal of air pollution control in the context of transport (Bundesministerium für Verkehr und Digitale Infrastruktur, 2020). The UDT initiative expanded further with around 30 million euros in project volume from the federal "Smart Cities Model Project," establishing the "Connected Urban Twins" project alongside Leipzig and Hamburg to promote knowledge transfer between municipalities and citizen participation. [8] Approximately one third of the project budget is available to the City of Munich.

Twinning the city: the making of UDTs and urban governance

In the following sections, we look into the UDTs of Boston, Namur, and Munich in the making, asking how these UDTs take shape and evolve together with governance approaches in specific urban contexts. We analyze our cases through three key themes where mechanisms of twinning—namely, the interrelation between technology, knowledge, and governance—become most evident: the representation of the city as part of the UDT, the epistemic promise of the UDT, and each city's vision of desirable governance expressed in and enabled by the UDT.

Representation

Our analysis shows that the process of twinning reflects locally embedded political priorities and contexts on a material level. Each UDT encapsulates themes and ideas that are locally significant; these, in turn, influence how the representation was developed, how interaction with the tool is enabled, the knowledge it provides, and the specific realities it suggests.

The Boston UDT bears traces of its origin context—the need for a shadow analysis for a controversial development project, as mentioned earlier. Even today, the UDT is conceived and used rather focused in terms of urban planning and development review, which fits with it being overseen by the BPDA (and now the Planning Department). Specifically, the representation of the city includes aspects defined by Boston's zoning code, particularly "Article 80," which specifies the conditions under which proposed buildings must undergo an official review process and meet specific criteria. As one interviewee points out, Article 80 comes into play "if it's a building that is greater than a certain number of square feet [. . .], they have to go through this process with the BPDA to get approved" (consultant, January 2023). The UDT shows which buildings are currently within the legal process for development review and what their status is according to its logic: As another interviewee describes, after updating the model, visitors can now choose to see the "existing" or "future" city, including the status with different color coding. Appearing as an overview platform of development projects within Boston, it also provides information such as the address, project ID, and status.

Namur's UDT shows the 3D geometries of approximately 45,000 buildings of the city, as well as the textures of the buildings' fronts. In developing the model, the minister and the administration established a set of specifications that contractors should follow; the model had to be 3D, cover the whole municipality, and model a set of specific things: all textured 3D geometries of the building, the calculation of roof photovoltaic potential, and the aerial thermography of the municipal territory. Accordingly, each building within the model is enriched with multiple layers of information, including its postal address, its year of edification, its photovoltaic potential, as well as the thermographic imaging of the roof. Importantly, the minister and his cabinet requested a public 3D web platform to make all data visualizable to citizens. This representation, and in particular the visualization of buildings' energy conditions in a publicly accessible way, not only reflects the

city's goal of fostering ecological sustainability but aligns with the goal to raise awareness and educate citizens on energy efficiency and climate-related issues that motivated the creation of this model. With homeowners being expected to make environmentally friendly renovations in their buildings based on the availability of such information, the UDT is imagined to serve as a tool for both governance and citizen involvement.

Unlike the cases of Boston and Namur, Munich's UDT cannot be pinpointed to a single entity or location. Different interviewees describe the UDT as an "ecosystem," "foundation," and "central data hub for everything you want to do in the city" (start-up partner, July 2023). This ecosystem links diverse digital resources across the city within an integrated urban data platform. Implied in Munich's understanding of a UDT is also an open data portal which makes certain data publicly available. Priorities within the initial twinning process bear traces of the early funding programs through which the UDT was developed, i.e. the link between mobility and clean air, and the focus on traffic and mobility data. Accordingly, achievements as part of the UDT so far include work on a cutting-edge model of the street space, a LANE model, which not only visually represents streets and other elements, but also traffic rules, and 3D visualizations of new cycle paths in different areas of Munich. These efforts demonstrate how Munich's UDT is envisioned as a dynamic platform that integrates diverse representations, enabling data-sharing across city departments and aligning with governance priorities. Within further funding programs and collaborations, topics such as integrated urban planning, participation, and climate neutrality have also become important areas of interest for the UDT.

Across the different cases, our analysis not only shows that a city's governance priorities are emphasized in the representations within their UDTs but also influence how administrations gather and communicate information about specific issues. The underlying structure of each UDT reflects how the actors imagine working with these tools. The representation has implications for further materialities, such as the knowledge-infrastructure necessary for maintaining the UDT. Thought further, this again invites us to reflect on the selective processes of twinning and to scrutinize which aspects have not been prioritized and represented, thereby linking back to discussion around what a "twin" is supposed to convey. Ultimately, the aspects and dimensions made visible through the UDTs may shape how urban problems are framed and define the possible avenues for their solution.

Epistemic promise

As described earlier, one assumption regarding UDTs is their potential to improve urban governance by enhancing the knowledge base and information systems of the city. To understand better how UDTs take shape hand in hand with ambitions of urban governance, we trace in which ways actors consider the UDT to improve knowledge about the city, and how this is reflected in the twinning process. Actors seem to share the underlying assumption that the UDT can transform complex urban information into actionable insights that are easy to understand and communicate, thereby supporting more informed and effective urban governance and decision-making. This epistemic promise takes different nuances in the twinning process in each of the cases.

In Boston, the actors' expectations toward the UDT as a way of knowing the city also reflect the primary objective to enhance the efficiency of the BPDA's work and improve

the urban development review process. The UDT project is valued for the opportunity "to quickly do design studies in context" (consultant, January 2023), which is achieved by the ability to visually place urban design and development plans in a broader context and offer a holistic view beyond individual buildings, a feature that actors emphasize as crucial for effective urban planning. This goes hand in hand with the bridging of professional conventions of architects, designers, and GIS professionals, integrating their respective perspectives and software tools. The UDT supports the ambition to "streamline the development process" (administration worker, November 2022b), and to create a "one-stop-shop" (administration worker, November 2022a), a comprehensive system where information, tools, and resources for planning, analysis, and decision-making are accessible in one platform.

In Namur, the UDT promises to make abstract sustainability concepts tangible. As a new tool within pre-existing urban sustainability policies, the UDT is said to enable the visualization of previously invisible phenomena, allowing stakeholders to gain so-called "objective" knowledge on an important component of a city's urban planning (members of the administration, April 2023). Here, great emphasis lies on an educational intent: by providing detailed and accessible information about the city's energy efficiency and climate-related initiatives, for example, on buildings' photovoltaic potential and thermographic imaging, the UDT aims to educate citizens on energy conservation and environmental issues. This educational function is tied to aspirations of fostering public engagement and community-wide commitment to sustainability, bridging the gap between governance and citizens, using data-driven insights to motivate public action and support the city's ecological goals.

In Munich, integration of knowledge and different (data) sources is a key promise. The UDT is imagined as helping "us to bring this various complex information together" (administration worker, March 2023a), facilitating a holistic understanding of the city's complex urban landscape and its various sectors such as mobility, energy or climate, through an up-to-date database. This approach seeks to dismantle traditional departmental silos, allowing data and expertise from various sectors—transportation, environmental management, and urban planning—to interact seamlessly and foster interdisciplinary collaboration. The UDT is hence an expression of integrating knowledge beyond administrative boundaries and thereby improving planning and decision-making in the city. The epistemic promise thereby extends to organizational learning, to overcome the problem that as in large corporations also in administrations "sometimes the internal departments don't know what the others are doing" (administration worker, September 2023).

In all three cases, the UDT is not only about making use of data, but tied to the ability to speak about different parts of urban life simultaneously and more efficiently. Part of the promise of UDTs is their imagined capacity to make the abstract tangible and the invisible visible. By transforming numerical data into visual representations, they are assumed to provide a clearer understanding of potential impacts and facilitate comprehensive assessments. Through the accessibility of complex information, actors not only expect better decision-making but also better comprehension among non-expert actors and the public. Actors expect that this enhances transparency and public engagement by clearly communicating urban issues and policy impacts, which will be discussed in more detail in the next section as part of the vision of desirable governance.

Ideas of desirable governance

How do the actors envision desirable governance in their city, and how is the UDT framed as an effort aligned with that vision? How does twinning materialize in the way desirable urban governance is imagined? Our observations reveal that actors often emphasize traditional efficiency narratives of their use of technology. UDTs seem to promise that instruments and processes become faster, more efficient, less error-prone, and more integrated. In a way, the UDTs in all cases are aligned with a hope for technological "salvation" to urban problems, as has been argued with regards to the smart city narrative (Sadowski and Bendor, 2019). In addition, actors' ideas of desirable governance are deeply intertwined with the previously discussed themes of representation and epistemic promise, highlighting how knowledge-making practices influence their aspirations for governance.

In Boston, the development of the UDT embodies an idea about what the development review process is envisioned to become in the future. The desire for a "one-stop-shop" suggests an efficient, straightforward process that should make it easier to manage the regulatory framework of the process. Since the project was also about protecting Boston Common Park, among other priorities, this shows the importance of local landmarks, protected by legal frameworks, in shaping the urban development process. It is worth noting that the development review process and zoning code have long been a political issue. The current mayor of Boston has made the transformation of the BPDA and its planning practices a central part of her policy work (Wu, 2019)—indeed, in July 2024, the new Boston Planning Department had been launched (City of Boston, 2024).

In Namur, the 3D model is framed with a dual link to governance. First, in terms of a governance that can produce informed citizens by providing transparent, objective data on sustainability-related issues communicated in a pedagogical manner. Citizens, once informed through visualizations of the level of insulation and the photovoltaic potential of their home, are then expected to act accordingly and renovate it. This expresses an approach to governance in which public authorities benefit from their capacity to represent the city through the production and treatment of data, raising citizens' awareness and engaging them in the realization of pre-existing urban policies. Second, the 3D model is also positioned as a tool to strengthen public sector authority in urban governance, re-balancing power dynamics with private sector actors. By "showing things in a transparent, non-arbitrary manner" thanks to data, the 3D model provides public authorities with a tool to "hold their political line loud and clear" in bargaining with private companies about urban planning projects (minister, April 2023).

In Munich, the understanding of the digital twin as a "joint venture" (fieldnotes, February 2024) reflects the belief that future challenges demand governance integrated through collective efforts, emphasizing the epistemic promise mentioned above of a more holistic and integrated view of the city. One interviewee argues: "Some people are doing mobility, others are doing climate adaptation things [...]. And you can no longer solve these issues on your own. [. . .] Because everything is connected with everything else, especially in urban planning. And for that you need shared data, data sets, [...] shared planning" (administration worker, March 2024). In future governance, the silos between the 15 departments of the City of Munich are to be reduced. Thus, the UDT is intended to change the way administration works and solve problems of internal collaboration. As one interviewee said, "we will not reinvent the wheel" (administration worker,

March 2023b), rather it is about dynamically connecting things. And another one stated, "what I've learned most is that it's not really about technology or data, it's just about talking to each other" (administration worker, September 2023).

Across the cases, a shared vision of desirable governance emerges—one where innovative administrations leverage digital methods, technology, and data—raising questions about decision-making processes and democratic accountability. While in the cases of Boston and Namur the administrations seem to rely more on solutions provided by software companies, Munich's administration is trying to keep the competence in-house as much as possible. In Boston, one interviewee discussed the reliance on software firms, however, rather framed in terms of cost than creating or keeping the knowledge in-house. Interestingly, in Namur, another notion of sovereignty surfaces: by equipping public authorities with facts made visible, the UDT is expected to make governance more transparent and, hence, empower public actors in their relations to private ones. Thought further, this has implications for how administrations imagine their own role and govern the relationship with private sector actors and the public. This goes hand in hand with the imagined role of a strong administration, able to pursue innovative approaches under the lead of the public sector itself.

The actors' assumptions that the UDTs make certain topics and issues publicly accessible in an easily understandable way to a broad audience, such as the general public, are also connected to their observations of "a trend towards having a lot more democratic consultation when it comes to how money is invested in your local community" (consultant, January 2023; case of Boston). This includes the way of presenting information about the city, for example, visualizations, but also the improved availability through the Internet. The administration of Munich uses the visualization of planned bicycle lanes developed based on the UDT in citizen meetings, a potential that the administration of Boston sees as well. They frame this primarily in terms of their responsibility as a public authority, "always looking towards public transparency and accessibility" (administration worker, November 2022a). In Namur, the idea of informing citizens lies at the very heart of the motivation to create the UDT.

However, the promise that UDTs produce informed citizens, participatory governance, and spaces for the opening up of public problems and debates remains to be critically examined. Do UDTs replicate a deficit model of public understanding that ties in with the efficiency narrative of governance, where processes involving the public can be smoothed through "better" information and understanding? This question highlights a key limitation of this study: it draws on the perspectives of civil servants, engineers, and experts involved in UDT projects, but the empirical data lack perspectives from civil society and citizens whose lives these initiatives are supposed to improve. There may be differences between these groups in terms of expectations, experiences, or their engagement with these technologies. Citizen interviews and participatory methods thus represent an essential avenue for future research, offering a deeper understanding of how UDTs influence governance and participation from the perspective of those directly impacted.

Conclusion

By situating UDTs within the broader context of the transformation of urban governance induced by digital technologies, we examined the notion of "twinning" through the lens

of three UDTs in the making and their socio-political implications. We structured our analysis across three dimensions.

First, we considered the type of representation of a city that a twin is expected to provide. Through our cases, we showed that representations are heavily influenced by the governance priorities of cities, and that the underlying structure of the UDTs reflects how actors imagine working with them. Contrary to claims by UDT proponents, these representations are far from being objective or neutral "views from nowhere." Second, we explored the epistemic promises conveyed by UDTs. We highlighted that UDTs are not merely tools for processing data but instruments for integrating and communicating diverse aspects of urban life simultaneously. From this perspective, part of their appeal lies in their imagined capacity to make the abstract tangible, and the invisible visible. Third, we analyzed how twins are articulated with forms of governance deemed desirable. This articulation often crystallizes around the vision of an innovative administration that enhances its governing capacity through digital methods and data, shaping its interactions with private companies, contractors, and citizens. This, in turn, raises questions about decision-making processes and democratic inclusivity.

Building on our findings, our analysis leads us to offer a dual-layered critical examination of the UDT phenomenon. First, with respect to scholarly debates, we suggest that the analyses of (and debates on) such technologies can benefit from critique that goes beyond the smart city and datafication discourses. As our analysis has shown, the implementation of UDTs on the ground differs significantly from the rather abstract promissory discourse, including real-time data, ubiquitous sensing, or algorithmic automation. Not only might a critique that narrowly focuses on these issues miss other aspects that arise through the embeddedness of UDTs in a local context of urban governance, but it might also inadvertently reinforce the very narratives they seek to challenge by uncritically accepting the promises of UDTs.

Second, rather than merely showing that different digital twins are produced in different cities, the comparative, co-productionist perspective on the role of digital twins in urban governance points to a commonality across cases (Jasanoff, 2004; Joly, 2015): the dynamic interaction between city representation and governance, both of which are deeply embedded in larger local socio-technical contexts. By comparing the three cities, we gain insights into how and why actors give local meaning to the global trend, thereby framing problems, creating opportunities, and bringing together actors under the concept of the UDT in specific ways.

This analysis therefore underscores the broader implications for democracy and politics. Twinning processes selectively highlight certain public problems, influence the inclusion or exclusion of certain actors and the design of urban policies, constituting the second layer of our critique. These dynamics call on scholars and practitioners to critically examine whose interests, values, and visions of a good, desirable society and political decisions are incorporated into the UDTs, and which alternative perspectives are marginalized.

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Notes

1. In the literature, urban digital twins are sometimes also named "digital urban twins," "local digital twins," or "city digital twins."
2. Our case studies were selected as the actors themselves refer to them as urban digital twins. Remarkably, no urban digital twin project, to our knowledge, does fully meet the technical criteria of abstract definitions of "digital twins," but they are nevertheless examples of efforts to improve urban management through sophisticated digital models (for a similar argument, see Jeddoub et al., 2023).
3. On July 1, 2024, the City of Boston launched the new Planning Department, which has taken over staff and responsibilities of the former Boston Planning & Development Agency (http://www.bostonplans.org/news-calendar/news-updates/2024/07/01/city-of-boston-officially-launches-new-planning-de). Since the BPDA was the existing organizational structure at the time of data collection and writing of this research article, we maintain this reference throughout the article. We highlight the changes when it plays a role in the interpretation of the results in the analysis.
4. http://www.bostonplans.org/urban-design/urban-design-resources [as of May 2024].
5. The platform is accessible online via this link: https://www.le-nid.be/3d [as of May 2024].
6. As described on the NSS website: https://www.le-nid.be [as of May 2024].
7. https://muenchen.digital/projekte/digitaler-zwilling.html [as of May 2024].
8. https://www.connectedurbantwins.de/das-projekt-2/ [as of June 2025].

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