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Luigi Rullo

Paths of Digital twins in the public sector

A systematic review of the social sciences literature

PATHS OF DIGITAL TWINS IN THE PUBLIC SECTOR. A SYSTEMATIC REVIEW OF THE SOCIAL SCIENCES LITERATURE

Digital twins (Dt) technology is a remarkable revolution of our time, with the potential to disrupt all aspects of the public sector, government, and society. Combined with the rapid advancement of algorithms and related innovative technologies such as Artificial intelligence (Ai), blockchain, and Machine learning, using Dt opens a new and wide range of opportunities for the public sector. This article provides a systematic literature review on Dt, mapping and exploring the existing social science literature, to specify the scope and the nature of the concept and analyze the operational definitions of Dt and the relevance of the concept. The article is structured as follows. First, using the Preferred reporting items for systematic reviews and meta-analyses (Prisma) method, it gives an overview of the search criteria and the sample of records. Second, it reflects critically on the historical development of the concept of Dt and highlights its basic elements and ambiguities, shedding light on the theoretical and empirical gaps in the existing literature. Third, it explores the main initiatives and applications of the use of Dt, and argues that political science has much to offer in advancing global understanding of this emerging technology.

KEYWORDS *Digital Twins, Public innovation, Prisma, Government, Political science, Politics, Social Sciences.*

1. Why are we talking about Digital twins?

The massive spread of digital technologies as a social infrastructure has ushered in a new era, bringing about disruptive innovations in contemporary politics and society (Calise e Musella 2019). In the context of the current digital transformation, *there is something new in the sun today*: Digital twins (Dt). Dt represent one of the most challenging technologies, popular (Fig. 1),

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and cutting-edge topics in international academic research (Dahr *et al.* 2022; Holopainen *et al.* 2022; Crespi 2023). It can be basically defined as «a virtual representation of a physical system (and its associated environment and processes) that is updated through the exchange of information between the physical and virtual systems» (Vanderhorn and Mahadevan 2021, 2).

Spending on Dt technology development and adoption is increasing worldwide¹, with Forbes predicting that the global market will grow tenfold by 2030 (Kewley 2023). A recent Gartner (2023) report observes that by 2027, over 40% of large organizations worldwide will be using new technologies such as Dt to increase their revenue. Indeed, they have been providing a significant value to a wide range of private sectors rapidly becoming one of the pillars of Industry 4.0, thanks to its «plethora of advantages, including the reduction of errors, uncertainties, inefficiency, and expenses in any system or process» (Singh *et al.* 2021; Sun *et al.* 2022; Cooke 2021). At the same time, it represents a new source of competitive advantages for automotive, e-commerce, manufacturing, and logistics (Crespi 2023). In this respect, a study of Atos Italia e The European house – Ambrosetti (2023, 95), showed that a systemic adoption of Dt in the manufacturing sector would generate an increase in productivity of 4.5 % over the current (baseline) scenario, with an impact to Italian Gdp of about 12 billion euros, which corresponds to a structural increase of 0.7 percent of national Gdp.

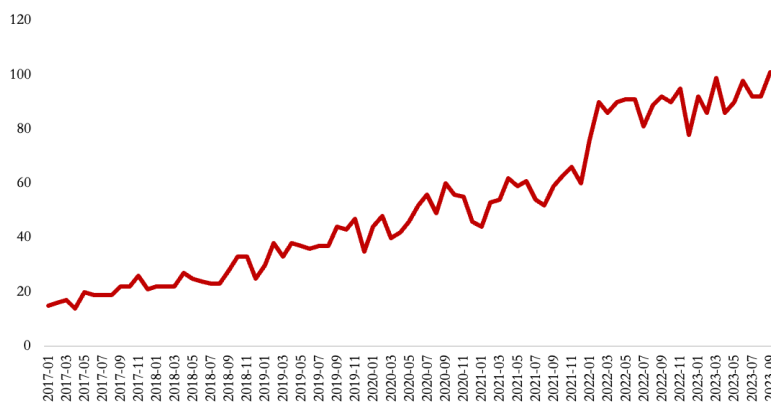


FIG. 1. Worldwide Google Trends for the term «Digital twins» (2017-2023).

Source: Own elaboration on Google trends. Note: until September 2023.

¹ Li *et al.* (2023, 13) presents an overview of the Dt patent landscape observing that in China «the number of patent applications has increased significantly since 2018, and in the same year, it has risen to the same level as the number of the Usa and surpassed the number of Germany for the first time. Therefore, China has become the top productive country in the world since 2019».

Likewise, governments are becoming aware of the potential benefits of developing and applying Dt. There is a spread of public interest, investments and research on this technology as a potential source for economic and social growth, being recently included among the pillars of the 2030 Agenda of the United Nations for sustainable development (Mabkhot *et al.* 2021). Moreover, Dt started to become one of the most promising avenues for the transformation of cities and urban management, through the spread worldwide of City Digital twins.

In such an evolving context, the academic enterprise working on Dt has increased across disciplines, with scholars attempting to provide overviews on the application areas (real and potential), benefits, main challenges, and – to a lesser extent – its conceptualization (Grieves 2023; Korenhof *et al.* 2020; Jones *et al.* 2020). At the beginning of the 2020s, however, the results in the international literature are less than satisfactory, or the best *in itinere*.

First, there is a general lack of consistency on what Dt are because of the growth of competing definitions and/or misconceptions, as well as an excessive emphasis on demonstrating technical functionality, thus providing a confused research plan and framework on terminology and categorization.

Second, most of the existing literature comes from technological or engineering studies ending to confine Dt to a technology-centric view (Nochta *et al.* 2021). As a result, while the existing literature may contribute to a fine-grained understanding of the strategies and technical applications of Dt, there is a lack of theoretical and political implications of these changes, especially from the perspective of democratic governance.

Third, while much political science-oriented research has focused attention on the disruptive innovation produced using algorithms in the public sector, approaching it from different and conflicting theoretical – and often ideological – angles, little effort has been made on the conceptual-theoretical analysis of the Dt. Consequently, the ways Dt can reshape the dynamics of governance, policymaking, and civic engagement are not yet properly understood.

This article presents a systematic literature review on Dt technology with special reference to the public sector, mapping and exploring the existing political and social science literature. A comprehensive scoping review is conducted through Preferred reporting items for systematic reviews and meta-analyses (Prisma) method, to deepen the understanding of how this concept has been used and thematized in the social sciences literature. The article is structured based on the following research questions/objectives:

- to specify the scope and the nature of the concept, and analyze the operational definitions of Dt and the relevance of the concept considering the existing social science literature;
- to identify the main applications of the use of Dt technology in the public sector;
- to highlight research gaps and suggest further avenues for political-science oriented research on this topic.

The next section presents the methodological aspects of the study, including the procedures for collecting and analyzing data. Then, the article presents the results, discussing the concept and the main areas of application of Dt. The last section concludes the analysis and argues that political science has much to offer in advancing the global understanding of this emerging technology.

2. Methods and overview of records

Willing to understand the evolution of the Dt technology in the field of political and social sciences and identify future perspectives, the Prisma method was used to review the literature² (Fig. 2). This method allows for comprehensive insight based on objective, replicable and transparent procedures and is widely used in academic research (Haug *et al.* 2024).

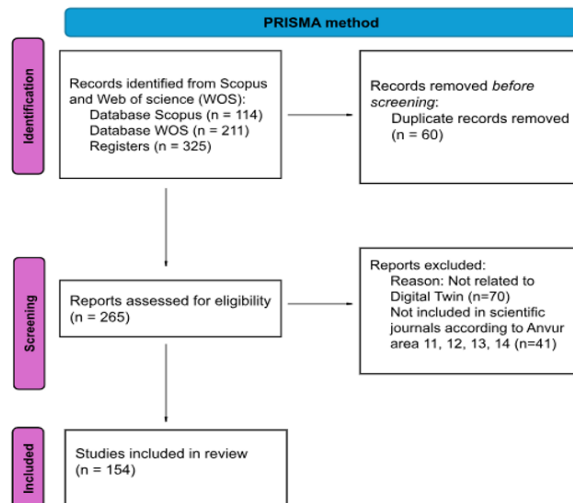


FIG. 2. PRISMA method applied in the analysis.
Source: Own elaboration from the dataset.

² See <https://www.prisma-statement.org/>.

The search was carried out in two databases, Scopus and Web of science (Wos), that are providers that link several multidisciplinary databases, especially related to the social sciences³. Moreover, as previous analyses suggest «the convenience of these interfaces in statistical database processing helps researchers to filter papers closely related to their research area» (de Oliveira *et al.* 2022, 180). The search was restricted to articles, books and book chapters and to the following languages: English, Italian, French, Spanish, German. The search in Scopus was limited to the social science field based on the query («Digital twin») and a set of ten terms (government, governance, policy-making, policy, bureaucracy, administration, public sector, public management, open government, transparency).

Only articles, books, and book chapters containing the combination of «Digital Twin(s)» and at least one of the above ten terms in their titles, abstracts or keywords were selected. In Wos the search was limited to the Social science citation index (cf. Terlizzi 2021). In this way, we aim to show what is the consolidated and consistent view of what the Dt are in the social science literature, and how – if any – the concept has been linked to the public sector in general. No time span was chosen, so that the most recent research should coincide with September 20, 2023, that is the day the search was performed. Figure 1 illustrates the process used, as well as further inclusion and exclusion criteria.

First, I merged the 325 records identified from the two databases (Scopus = 114; Wos = 211) and then removed 60 duplicates, leaving 265 reports assessed for eligibility. During the screening phase, I manually excluded 70 articles which did not focus on Dt based on titles, author keywords, and abstracts. For example, some records used the term «Digital twin» to refer to the «energy and digital twin transition» in Europe and have therefore been excluded from the analysis.

Second, I then matched all the records found with the record of the scientific journals in area 11 («Historical, philosophical, pedagogical, and psychological sciences»), 12 («Law»), 13 («Economics sciences and statistics»), 14 («Social sciences») as identified by the Italian *Agenzia nazionale di valutazione del sistema universitario e della ricerca* (Anvur) (2021-2023). These journals are recognized by the scientific community for the high standard in the quality of the articles. The inspiration for this screening *criterium* is linked to previous reviews on related themes, such as Terlizzi (2021), who studied the digitalization of the public sector.

³ The dataset generated for this is available from the author on reasonable request.

All the 41 articles not published in these scientific journals were excluded from the analysis, leaving 154 studies in our review. Of these, 140 are scientific articles, 11 are book chapters, and 3 are books. More in detail, the books ($N = 3$) included in our sample are as follows: *Artificial intelligence and playable media* (Freedman 2022), *Smart urban mobility: transport planning in the age of big data and digital twins* (Semanjski 2023), *Urban freight analytics: big data, models, and artificial intelligence* (Taniguchi et al. 2023).

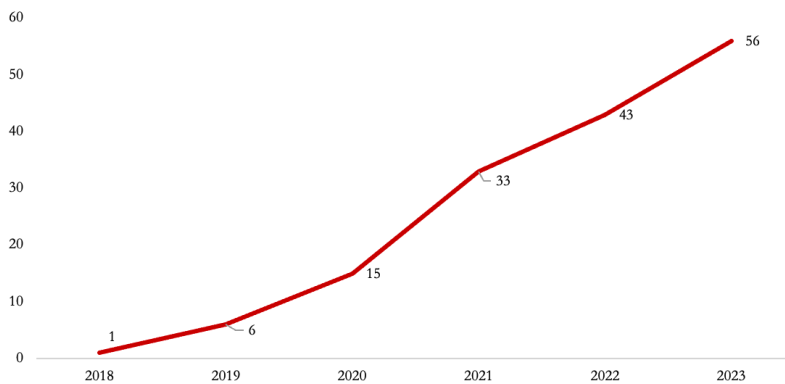


FIG. 3. Records published by year ($N=154$).
Source: Own elaboration from the dataset.

Only one record is in the Italian language and the whole is in the English language. According to the selected inclusion and exclusion criteria no relevant studies on Dt were published before 2018 (Fig. 3). Since then, the publication trend has increased significantly. Largely due to the implementation of this technology across a wide range of social realms and to a series of elements such as the advances in the commercial availability, a general increase of public and private investments, it can be observed a growing salience of the topic in academic research. Most publications appeared over the last two years, ranging from two publications between 2018 and 2020 to around 60 in the most recent phase, thus indicating that about 85% of the literature on Dt has been produced in the past three years (2021-2023).

Of the 77 journals that have been published on the subject, only 21 have more than one article, and of these, the academic journal that has published the most articles is «Sustainability», which represents 20% of the journals' total articles (Fig. 4).

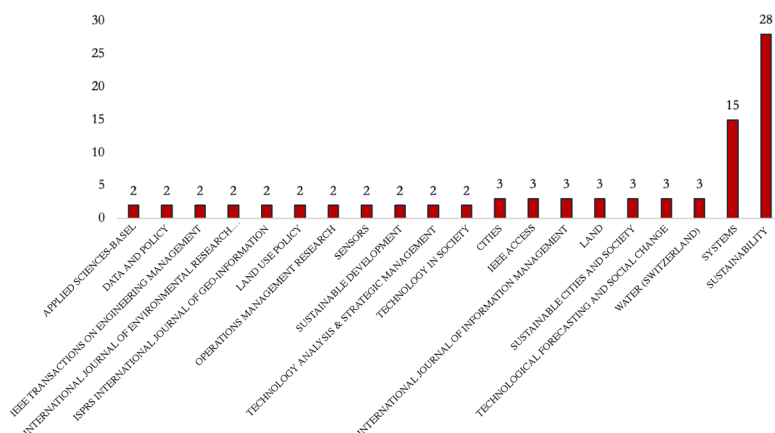


FIG. 4. Journal with at least two articles.

Source: Own elaboration from the dataset.

The countries of publication were also evaluated (Fig. 5) to show which countries were the most prolific in publishing articles on Dt technology. According to our data, Switzerland and the United Kingdom display the highest values, having published 61 and 48 articles respectively.

TAB. 1. Country of the publisher house

Country	N	%
Germany	10	6,5%
Italy	3	1,9%
Netherlands	8	5,2%
Switzerland	61	39,6%
UK	47	30,5%
USA	25	16,2%
Total	154	100,0%

Source: Own elaboration from the dataset.

This was followed by the Us, Germany, the Netherlands, and Italy with 25, 10, 8, and 3 respectively. The almost 40% of Switzerland is substantially since the two most prolific journals on Dt in our sample are «Sustainability» and «Systems» which are published by Multidisciplinary digital publishing

institute (Mdpi), a publisher based in Basel and one of the largest publishers of open access scientific articles⁴.

Regarding articles research areas, the rise of Dt has precipitated a transversal scholarly interest. Its rapid spread in many spheres of social activities stimulated the academic effort in different research areas to evaluate the specific challenges and substantive domains to provide a better understanding of this emerging technology (Fig. 6).

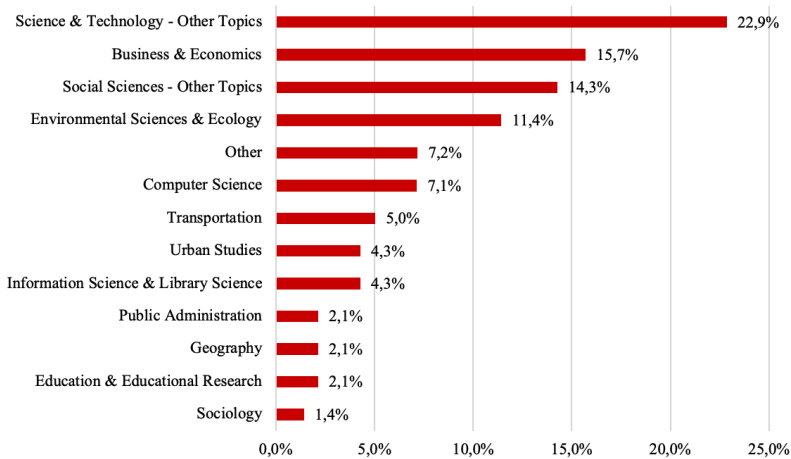


FIG. 6. Research areas of the journal articles (%).

Source: Own elaboration from the dataset.

More in detail, twenty research fields were identified from the extracted data. Half of the published records are related to «Science and technology» (22.9%), «Business and economics» (15.7%), «Social sciences – Other topics», and «Environmental sciences and ecology» (11.4%) thus confirming the interdisciplinarity of the topic under analysis. The gap between the first and the last research areas shows a clear progress in the research of Dt in the field of business and smart city, where the rise of digital replica of the real physical entity became more and more easily available, allowing for several experiences of real-time simulation connecting the physical and virtual world. Overall, the paucity of social sciences studies highlights the remarkable po-

⁴ The number of corresponding authors working on Dt by country reveal that the top five countries with the most corresponding authors are the United States, China, India, Germany, and the United Kingdom. China and Us have the most corresponding authors working on Dt, with respectively 17 and 14.

tential for studying the transformative applications and innovations of Dt in specific fields, such as political science and law, where no articles were found.

3. Digital twins: concept and practices

Concept

From the ritual behind the Western notion of «voodoo doll» to the cyberpunks' virtual world, the desire to replicate – and control – the physical world in a fully (machine) readable form is a longstanding aspiration that has resonated with humanity for centuries.

Beyond sci-fi studies, historically, the development of maps introduced a new way of thinking about the world (Lentini 2005; Musella forthcoming). Rooted in the advancement of science, maps have been a significant milestone in the socioeconomic and political projection and representation of the world, disrupting the cognitive patterns that had dominated for centuries. Indeed, the availability of a new method for comprehending and structuring reality based on empirical findings gave rise to an indispensable tool for gaining political, military, and economic control over territories⁵. The representation of physical objects or spaces in a structured, organized, and systematic manner through cartography was at the basis of the expansionist activities of European countries throughout the XVII centuries. Maps soon became a practical way to identify safe shipping routes or sites of natural resources to be exploited. At the same time, largely due to «the values of mathematical exactness and the correctness in which borders, roads, canals, windmills, et cetera, are shown» (Lentini 2005, 59), they made possible the first form of «government of planning». Maps thus concretized as an instrument of power for modern States, acting as both as a device for understanding, interacting, and transforming the spatial reality, and as a panoptic control over territories, facilitating governmental control and discipline of communities.

Likewise maps, Dt are emerging as a new way of *decision on* and *representation of* the real-world. As Ng (2022) observes they «do not simply reflect reality or create fictional ones but are committed to remaking reality over and over again». Although some authors connect the idea of Dt to David Gelern-

⁵ The level of control on reality is basically shaped by the technology employed to know it. For a discussion on how maps represent along with census and museums an «institution of power», and their role on how colonial States imagined their dominion see Anderson ([1983] 2006, 163-185).

ter in his book *Mirror Worlds* (1992), the authorship of the term should be traced back to Micheal Grieves, an aerospace expert and Nasa consultant, in a 2002 presentation⁶. Yet, as reported by Grieves himself (2023, 101), while formally describing Dt in the context of his Product lifecycle management (Plm) works, until 2010s he did not even give that name, which was described as «Mirrored spaces model» or «Information mirroring model». Later, he attributed the authorship of the term to his colleague John Vickers of Nasa in a footnote of the white paper «Digital Twin: manufacturing excellence through virtual factory replication» (Grieves 2010). Here, we can observe one of the first conceptualizations of Dt as composed of three main parts:

- physical products in real space;
- virtual products in virtual space;
- the connections of data and information that ties the virtual and real products together.



FIG. 7. Basic elements of a Dt.
Source: Own elaboration.

Since its early introduction, this basic three-element model has deeply influenced other current definitions of Dt, which are often conceptualized based on «what» is being twinned. References to «physical system», «physical product», «physical artefact», «physical world», «physical object» are among the most frequent terms in our co-occurrence of authors' definitions' maps (Fig. 8). This suggests that the materiality of the «twin» refers to what already exists «objectively» somewhere, which can be also further specified based on the «real-life» entity under analysis like human body, land, port, manufacturing, infrastructure, or even ocean⁷. According to a large amount

⁶ Most of the papers link the concept of the Dt to the Nasa in the Sixties as a means of simulating spacecraft for the Apollo 13 program. However, as Grieves suggests (2023, 101) (who met the Commander of the Apollo 13), «the “twin” involved in working the problem on earth was a physical twin capsule simulator. It had very little “Digital Twin” about it. [...] There was no digital twin capability».

⁷ See The European Digital twin of the ocean (Dto) announced in 2022 by the European commission: <https://research-and-innovation.ec.europa.eu/funding/funding-op->

of literature, therefore, Dt is «a dynamic virtual representation of a physical object» (National infrastructure commission 2017), a «digital replica of a physical entity» (Ukko *et al.* 2022), «a digital counterpart of the physical systems» (Kamble *et al.* 2022), «an exact cyber copy of a physical system» (Alam and El Saddik 2018, 2051; Marcucci *et al.* 2020), or of «what we are accustomed to watch daily» (Kendzierskyj *et al.* 2019).

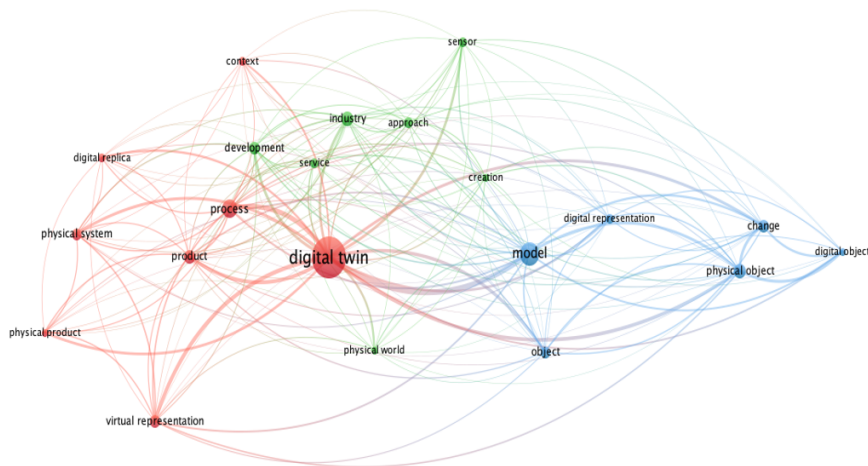


FIG. 8. Co-occurrence of authors' definitions' network visualization map for literature in Dt (threshold of 10 occurrences; display of 21 words).

Source: Own elaboration from the dataset.

However, Dt refer not only to physical (built or natural) material entities, but also to processes, and organizations (Lyytinen *et al.* 2023), and even *persona* (de Kerkove 2021). This awareness signals the main evolution – or transmigration – of Dt beyond the industry and manufacturing field, and the main route to appreciate the extension of the concept to the social sciences field. One is talking about an airplane and its respective product and process design; another would be talking about an organization such as a complex public administration. This in turn affects the level of fidelity of the Dt representation. In fact, we can distinguish the «target» of twinning first and foremost on its level of observability, as the original physical design from which a digital representation is built is not always immediately apparent. For example, the reflections, at this time at their infancy, on «organizational digital twin» (Parmar *et al.* 2020), «digital twin of a holacratic organization» (Winkler and

opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/restore-our-ocean-and-waters/european-digital-twin-ocean-european-dto_en. See also Destination earth: <https://destination-earth.eu/>.

Kremser 2023), or «digital twins of organization» (Lyytinen *et al.* 2023, 1) represent a promising avenue to «design, implement and test interventions in organization, and then run “what-if” scenarios based on complete, up-to-date information».

The second basic element of the Dt is the «virtual representation», «cyber copy», «digital representation», «digital model», or, more simply, «digital replica». While the terms «virtual» and «digital» are used interchangeably, the commonly accepted characteristic is that the output of the «twin» is ontologically identifiable as a «digital (arte)fact». However, Dt are not just scientific abstractions of reality, because they try to go beyond abstraction and dynamically represent all functionalities of a concrete physical entity, system or process through real-time data updates. Therefore, to better establish and define what Dt is, we should try to establish what Dt is not. Following Sartori (1987, 182), «the standard manner of delimiting a concept is to define it a contrario, by contrast, i.e., by establishing its opposite, contrary, or contradictory».

Looking at our concept, this is primarily based on the nature of data flow, which should be bi-directional and real-time (Kritzinger 2019). Here we can find the main differences – and confusion – with other modeling or simulation technologies such as Digital model (manual data connection), Digital shadow (only one-way physical to cyber connection), simulation (not dynamic and there is no real-time connectivity), holograms, avatar, or cloning (no real-time synchronization of data) (Ramu *et al.* 2022, 2). Therefore, space and time combine in the Dt, with disrupting consequences on both. This is the main reason why some authors have linked the concept of Dt to the Metaverse – either by claiming that the former is the building block of the latter or by overlapping the two so that the Metaverse becomes «a digital twin of the real world» (Baker *et al.* 2023). In this respect, for example, Buhalis *et al.* (2023) observe that «metaverse is an all-encompassing virtual world that exists in parallel to the physical world. This is more accurately reflected in the term “digital twin”».

In other words, the equivalence of the cyber-physical entities is so complete that the digital artifact is not only its «live mirror» but may also have a control function over the physical one. Thus, changing the state of the digital artefact results in changing the state of the physical object and *vice versa*. On this point, Nochta *et al.* (2021, 268) emphasize that we can appreciate the usefulness of the concept beyond the industrial field if we go beyond the pure convergence between physical and digital entities, claiming that Dt are analogous to organisms «with a brain». De Kerkove (2021) goes further and speaks of the «Personal digital twin» to describe how, as human behaviors are progressively shaped by computer algorithms, the path to a posthuman world

is being set in motion. Individuals are transformed into quantifiable subjects by a second self – the Dt – that can access, record, analyze, and compare current and historical data not only through what it knows through its physical double, but also through the elaboration in the online world (cf. also Koppo-nen 2022; Fraioli 2022).

The third and most controversial element of the basic characteristics of Dt technology is the interaction between the physical and digital artifact. The architecture generally consists of four main phases: data acquisition, transmission, data-model integration, and application (Mihai *et al.* 2022). These elements, however, seem to be the least problematized, with most of the published literature focusing on the different modeling and simulation techniques that enable Dt creation and management⁸ (Attaran and Celik 2023, 2). Enabling technologies such as big data, IoT, software, databases, 5G, sensor networks, cloud computing, analytics and Artificial intelligence (Ai) became «taken for granted» elements. Yet scarce attention is paid to the characteristics of the real-time data, their availability and quality, being used for the connection between the physical and digital artefact, and the implications of using them for understanding, learning, and managing Dt. In such a scenario, Dt technology is first and foremost a digital representation in terms of the data that is or is not part of it, so that a Dt exists and consists of data. Consequently, only what is datafied will be included in the Dt. For example, we can well understand the health of a baby if we datify its weight and height, but not its happiness so that Dt, at this moment, can «perform poorly with regard to many hardly measurable qualities that humans care about» (Helbing and Sanchez-Vaquerizo 2023, 98).

Applications and research gaps

Looking at the applications and challenges of Dt in the public sector, the literature has investigated several areas and domains where this technology can be applied. Scholars have been surveying different areas of interest, providing specific examples of Dt, presenting exploratory applications based on case studies, sustainable developments or speculating on future projects, with most of the analyses focusing on City Dt implementations and urban management. This is witnessed – among others – by studies on national and supranational initiatives such as European union's «Duet project» and «Lead

⁸ Nevertheless, to enable the development of practical solutions with such technologies, it is necessary to revise the development processes, which must be able to adapt to speed and continuous changes.

project»⁹, the Uk's «National digital twin program», Singapore's «Virtual Singapore project», South Korea's «Seoul S-Map»¹⁰ and «Sejong city digital twin», India's «Amaravati», as well as other local Dt cities which have been spreading across Europe. Dt helps to model, visualize and understand the city environment, manage resources (Park *et al.* 2023), monitor environmental sustainability and urban mobility (Papyshev and Yarime 2021), and plan urban spaces for citizens' well-being (Yossef Ravid and Aharon-Gutman 2023). For instance, in the Docklands area in Dublin, a recent project allows government agencies to visualize urban changes and gather citizen feedback before implementing new policies through Dt (White *et al.* 2021).

Moreover, the massive proliferation of Dt has sparked debates about the impact on digital government transformation, investigating how they can stimulate a redefinition of public administration role and traditional Weberian methods of operation, and assist bureaucratic functions (Eom 2022). In this respect, bringing together hardware and software (Musella 2022), this technology can drive the innovation into the design and operation of public administration, which can benefit from these developments «to solve policy problems in various fields, including employment, business, transportation, environment, welfare, safety, and urban architecture» (Eom 2022, 181). While there are concerns about these developments in terms of formal control (Ukko *et al.* 2022), and the need for development of new skills of employees, the main idea is that through Dt, public services will be better planned and governed, as decision-makers will be able to serve citizens better and resolve arising problems faster through well-informed policy decisions.

Particularly, Dt can create a «paradise» for decision-makers in times of emergencies: all potential scenarios can be evaluated limiting harm, waste or cost, by providing real-time data and simulations for informed decision-making facing crises (Chioni *et al.* 2020; Fan *et al.* 2021). For instance, Dt can guide emergency evacuation, help optimize evacuation routes of public buildings, improve public safety measures (Han *et al.* 2020), and grant a more efficient public supply chains for essential goods such as masks during the Covid-19 pandemic.

Finally, Dt are making strides in the education and health sector. In relation to the education sector, studies have observed how Dt can transcend the limitations of physical space and traditional classroom boundaries (Rajabifard *et al.* 2021). Wu and Tao (2023), starting from the concept of «EduMetaverse», illustrate how the integration of Dt with augmented and virtual reality

⁹ See <https://digital-strategy.ec.europa.eu/en/library/local-digital-twins-forging-cities-tomorrow>.

¹⁰ See the project S-MAP of Seoul, Southern Korea: <https://smap.seoul.go.kr/>.

(Ar/Vr), sensors, Ai assistants, and brain-computer interfaces enables a seamless fusion of the virtual and physical teaching environments, with students and teachers as avatars. Arantes (2023) explores the personalization of education, exploring how and why «the classroom of the future may be a space where things speak to students through personalized insights, adaptive responses, and chatbots». In healthcare, the use of Dt has already allowed real-time diagnostics or personalized treatments to make the healthcare sector more effective, efficient, and safe (de Boer 2020; Kendzierskyj *et al.* 2019). Some studies have investigated how people, objects, and processes can be monitored through sensors and how Dt technology can optimize clinical and non-clinical service delivery (Han *et al.* 2023).

Overall, while social sciences research on Dt is still scarce, the techno-imprinting and techno-optimist views of the Dt are evident in the existing studies. Most of the current analyses are occupied in showing the positive qualities of Dt, such as «increased efficiency», «oversight», «predictability», «improved decision making», «real-time monitoring», or «reduced downtime», stressing the positive effects of the mix of exploration, guidance and gamification that Dt can offer. Korenhof *et al.* (2023, 1756), for example, characterize Dt based on five main benefits: «real-time»; «high fidelity»; «predictive» (as far as they identify patterns of future behavior); «prescriptive» (as far as shape future behavior); and «feedback». In this way, however, what Dt *should be* is being separated from what Dt *is*.

In such a scenario, the integration of Dt technology in the public sector needs to be further systematized, raising several issues that require a more critical approach to understand a range of political implications, starting with the transparency and inclusiveness of data management. While Dt offers substantial potential by merging digital and physical systems, its reliance on data is not without bias. The process by which data is included and updated within a Dt reflects specific priorities which are not neutral (Calise and Musella 2019). This point introduces critical questions about which data are prioritized within the system as well as the managing and sharing information across public organizations, echoing concerns about interoperability and cybersecurity issues.

Second, because Dt involves decisions about not only what aspects of reality are included, but also by whom, the very representation of physical entities in a digital format is a political act. In a nutshell, the representation of the given entities is the product of a precise political choice in the hands of «who» govern this technology. Echoing the McLuhanian idea that «first we build the tools, then they build us», the leakage of sensitive information which piece together different databases and private platforms, could provide a fuller picture of individual citizens, public organizations and society at large, espe-

cially in the context of increasing privatization of infrastructure and data ownership¹¹. The choices on what driving force control the service ecosystem for citizens have significant implications particularly in situations where private corporations define the rules of data access and extraction and already controls large portions of Dt infrastructure (i.e. Siemens, Samsung, Microsoft's Azure, Aws). In South Korea, corporations like Samsung are involved in the creation of Dt for military applications, illustrating how public-private collaborations in this realm can shape national security and citizen privacy.

Third, the legal implications – and risks – of giving consent to the processing of personal data and the collection of private data from public interactions are not adequately assessed¹². It is not difficult to imagine the values that a «citizen Digital twins» data can reveal, nor is it difficult for those who manage and regulate access to this data wealth. In China, for example, the introduction of the Social credit system, a kind of digital twins of citizens, has made it possible to tighten control over citizens by using a massive amount of biographical data. Indeed, «instead of creating politically aware citizens, the Chinese one-party security state has now resorted to the production of data subjects susceptible to digital control and manipulation based on pre-inputted parameters and algorithms» (Mennicken and Salais 2022, 90). In a democratic context, however, a reliable Dt should ensure transparency and trustworthiness of public data (Wang and Burdon 2021), promoting accountability and responsiveness in the context of government digitalization strategies and existing regulatory framework.

Lastly, future analysis should better highlight strengths and weaknesses as well as opportunities and threats on democratic citizenship (Tomko and Winter 2019, 23; Kopponen *et al.* 2024). To what extent does Dt technology involve citizens in decision-making processes and promote inclusivity and participatory governance? What are the consequences of a possible controlled participation, with a limited influence on political decisions and a concentration of power? The existing literature seems to forget how and why citizens can

¹¹ As Crespi *et al.* (2023, 1211) observe «some major software actors (e.g., Amazon, Microsoft, Google) are offering middleware and platforms supporting the Digital Twin approach, while simultaneously, open source solutions are emerging for creating Digital Twin applications (e.g., Eclipse's Ditto, Fiware)». For example, Twinzo created a Digital Twin of smart offices in buildings in several European capitals (London, Bratislava, and Budapest), which helps to monitor the movements of employees and visualize the occupancy of desks and rooms gathering real-time data from the environment. See: <https://partner.twinzo.eu/blog/solutions-2/digital-twin-for-smart-office-6>.

¹² For these reasons, the literature should not overlook the vulnerabilities shaped by human factors and governance contextual factors, which, for instance, contribute to cybersecurity issues and can inform the more effective use of Dt in public sector infrastructure.

benefit the most from this technology, also in terms of mass personalization of government services. The role of citizens/people in terms of trust, representation, and involvement is still under-researched and under-conceptualized in the Dt research agenda, thus opening further areas of research.

4. Conclusion

The rapid spread of Dt has attracted great attention from researchers and practitioners, bringing about disruptive innovations in contemporary politics and society. This paper presented a systematic literature review on Dt, mapping and exploring the existing social sciences literature. Unlike previous analyses, this article presented a different perspective of Dt research, emphasizing the social sciences approach to the Dt concept and its applications. The results suggest that there is room for further research for other social sciences such as political science, sounding like a wake-up call to better address the current and upcoming scientific and societal challenges, through a more systematic analysis of the impact and characteristics of this technology.

The history of our rapidly evolving concept first captured the positive slant that has accompanied the spread of Dt in many spheres of social activities. As Calise and Lowi (2010, 3) observed «the meaning of any concept depends not only on the defining words and attributes themselves, but on the choice of context. Designative words are one thing; concepts essential for a field of thought are quite another matter: they are never context free». As observed, the techno-imprinting and techno-optimist views of the Dt appeared clearly, pushing for integration and, to a certain extent, a shift towards a more critical approach. Therefore, the article advanced the process of extending the Dt concept from its traditional use in industry and engineering to the field of political science.

Existing studies to date do not seem to have adequately addressed some fundamental issues of digital politics. In this respect, the article observed strengths and weaknesses which emerge from the existing literature and stressed that further studies should better highlight the challenges and limitations of Dt, emphasizing sensitive socio-political issues, including data security, integration issues, and the need for specialized skills when – and if – Dt technology are applied to the public sector. In such a scenario, seeking the best collaborative implementations between scholars from different fields is an important first step in creating an equally accessible and understandable environment for the understanding of the rising Dt technologies. Particularly, without the integra-

tion of political science and related fields such as sociology, the full potential of the Dt cannot be realized.

To sum up, «the navigation of political science will continue to be perilous and difficult, to the extent that politics is neglected – be it because it is made peripheral, be it because it is declared heteronomous – to the same extent politics escapes control and becomes once more a force ‘out of control’. At one extreme, we have science eating up politics; on the other extreme, we have politics eating up science. The two extremes touch and transform themselves into one another. It is the task of the political scientist to shun it» (Sartori 1972, 263).

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