How to regulate a Digital Twin City? Insights from a Proactive Law approach

How “human in the loop” and “precautionary principles” can serve policymakers in their attempt to incorporate respect of rights and solidarity in the smart city.

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ABSTRACT

The paper aims to investigate, with a proactive approach to law, some of the core principles at the base of the Digital Twin Cities regulation. To do so, it briefly presents the debate on the inner vision in smart cities projects (and, consequently, also in DTC projects), moving from the ongoing debate between the “City as a Computer” as opposed to the “City as a Living Organism”, to arrive to a more practical approach – for the purposes of this work – formed by the dichotomy “Real-Time DTC” as opposed to “Simulation DTC”. Analyzing those scenarios, the principles of “human in the loop” and “precautionary principle” will be proposed to respond to the “Real-Time DTC” criticality, while also the “Simulation DTC” will be highlighted as a challenge for the lawmaker in its implementation.

KEYWORDS

Digital Twin City, Real-Time Technologies, Simulation, Human in the loop, Precautionary Principle

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1 INTRODUCTION - DIGITAL TWIN CITIES AS A FRONTIER

“Digital twin cities” are emerging as a frontier topic in studies on the digital transformation of cities.

In IoT, ’Digital Twin’ refers to a digital artifact that receives information from the physical object of which it aspires to be a copy. It can be used to simulate wear and tear and perform preventive maintenance. This concept has been gradually transferred to cities, especially in the last five years as a vehicle for a certain number of innovations. From 3D modelling to Smart grids, from augmented reality to urban experimentations at a various scale of complexity, the term “digital twin city” is plural, ambiguous and fascinating enough to attract the attention of the most important cities globally. Most specificities are about (aimed-to-be) virtual replicas of physical cities that allow for real-time monitoring, analysis, and simulation of urban systems and services. To achieve this, Digital Twin Cities generally require the integration of various data sources, including various types of sensors and social media data. The state of the art would require interoperability between various systems and technologies, such as IoT devices, cloud computing, and AI, to create a seamless and integrated virtual model of the city. Engaging citizens, businesses, and government agencies in the development and implementation of the virtual model ensures that the digital twin accurately represents the physical city and meets the needs of its stakeholders.

Most of the legal questions posed by the DTCs seem related to its own conception. In case the DTC is simply a cumulative way to refer to a list of smart cities projects [1], even if coordinated among themselves, legal questions are not different from the legal questions already present, and posed, by each of these projects. In this meaning, “Digital Twin City” seems not to differ significantly from “Smart City”, an umbrella name without practical implications, and to-be specified on a case-by-case basis. However, “Digital Twin City” seems to refer to something else, and in particular the use of the term “Twin” evokes the possibility of a truly comprehensive and identical copy of the city. In this case, legal implications are still largely unexplored, having to deal with frontier topics (like the possibility to represent in digital data the complex relationships between different parts of the city), or with unclear limitations (like the exact existing boundaries in personal data collection and aggregation to manage the city). The paper intends to explore this second meaning of DTC, in its present and future applications.

The scale of the projects and their size show that we are at an early stage of their implementation, but it is clearly emerging that:

the DTC model can be applied on very different cities of origin and extraction[1];

the DTC model can be applied on very different scales of city size[2].

The topic has already been present in the industry for several years, while initial literature reviews [2] aim to highlight:

the fundamental components of a DTC;

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[1] There are examples from the USA to Asia, including Europe.
[2] Cfr. Projects from Plzeň, Czech Republic (165,000 inhabitants) to Barcelona, Spain (4,840,000 inhabitants in urban area).

the levels of which a DTC is composed;

the objectives of a DTC and the interaction with the real city.

The doctrine is agreed that a digital twin consists of three basic parts: the physical product, the virtual product, the connections tying them.

From a legal point of view (but the doctrine has not yet been interested in it) it is essential to establish the qualification of what is "digital twin city" and what is not.

Thelen et al. (2022) write very clearly at the beginning of their work titled "A Comprehensive Review of Digital Twin" that it is fundamental to distinguish between a digital model, a digital shadow, and a digital twin. The distinction is *unclear in many cases. Further, having a large number of vague and inconsistent definitions of digital twin circulating in the literature may adversely affect industry interest in the adoption of this technology, creating a barrier to unleashing the maximum potential of the digital twin technology (Wright and Davidson, 2020)*[3].

This need also emerges from the work of Shahat et al. (2021) [4] (in turn referring to a literature review done by Kritzinger et al. in 2018 on Digital Twin in manufacturing), when *distinguishing digital twins from other types of models is crucial to realize the applicability of utilizing the completely mirrored digital twin for city-scale modeling; that is, the level of data integration, which varies according to the type of model, between the two counterparts (digital and physical) of the digital twin is decisive in stating whether the developed model is a digital twin or not* [5].

For the purposes of this analysis, the distinction set out in [3], may be recalled, and summarized as follows:

Digital Models: It is argued that, for a digital model, data flow between the physical space and virtual space is optional, or at the very most, achieved manually.

Digital Shadows: For a digital shadow, data flow is unidirectional from physical to digital. But for digital twin, the data flow has to be bidirectional.

Digital Twins: When digital twin is used in control-related applications, the bidirectional data flow needs to be automatic, often enabled by monitoring and control software. For the application of digital twin to support decision making, such as predictive maintenance, the data flow from virtual to physical involves humans in the loop who carry out maintenance actions and, therefore, is not fully automatic but should be handled on time to avoid unexpected breakdown.

The problem of the underlying philosophy of smart cities projects is debated, as [6] exhaustively illustrated, but the positions can be reduced to two main opposing visions: "City as a Computer" as opposed to "City as a Living Organism". The author recognized that, within this paradigm in which Digital Twin technology deeply integrates hardware, software, and IoT technologies to enrich and improve virtual entities, the topic of smart cities still seems to be addressed according to an approach that does not deviate significantly from the theories that have concerned the city in the last century, and its technological transformation, especially the idea that imagines the city "as a computer" [1][6]. Many papers, lately, moved far from this view opening margin to implement the idea of a city as a living organism.

1.1 Implications and Limitations

The issue is particularly relevant for law and governance, since recognizing the basic approach of a project (especially if "totalizing" as that of a DTC) should involve the explanation, by the public administration, of the ethical-legal approach that underlies the digitization of the city. This is regardless of whether the Public Administration wants to give an impetus to digitization, or whether it simply wants to "regulate" it and govern its effects.

This approach, however, is not without its problems. In this paper, we will start from this consideration to propose - for the purposes of this work - a temporary distancing from the debate thus posed ("City as a Computer" as opposed to "City as a Living Organism") and consider the typology of DTC projects according to a different clustering, defining some guidelines for DTC law with a proactive law approach.

To start the analysis, some limitations must be set. The paper will focus on the European context and the European legislative framework. Having to deal with the legislative framework from other Areas of the World, like the US or China, requires a much broader understanding of the DTCs and their legal implications. It is the opinion of the Author that establishing a single framework for significantly different cases could frustrate the possibility to establish useful insights and results at this stage of the debate.

Lastly, the paper will divide DTCs into two categories ("real-time DTC" and "simulated DTC", explained in paragraph 3). In practice, it is true that DTCs could assume a full spectrum of possibilities existing between these two "polarizations". The use of the two, however, is justified by the purpose of the article and to validate a possible cornerstone in regulating DTCs.

1.2 Why suspend the debate between "City as a Computer" and "City as a Living Organism": achievements and limits

The issue of whether the debate is correctly framed between "City as a Computer" and "City as a Living Organism" allows us to highlight the virtues and limits of this approach.

In many cases the approach used, and the underlying philosophy that guides the work of researchers and scholars, is rarely made explicit. Some papers "state" (or "suggest") one vision or the other. It's rarely presented as a debate, like in 5]. Sometimes, the way the project is presented depends on the academic field of the scholars, or on the topic.

Halegoua [6] reconstructed the debate by highlighting the two positions:

City as a Computer: The idea that the problems of the city can be solved by thinking of the city as a big computer.

Based on this idea is the attention to the regulation of flows, such as energy, traffic and waste [6]. Supporting doctrine comes from [7], which talks about experiences of "real-time organization" of the city, such as: *l'espace urbain comme un résultat sans cesse remanié par des opérations d'optimisation*[3]. This approach can come from a corporate view, as approaching the city from an engineering point of view, or dealing with the management of its flows (in particular, for smart cities, contributions in terms of traffic, energy

[3]Translated by the Author: "urban space as an outcome that is constantly being reshaped by optimisation operations".

and waste management are frequent) can only be brought under the umbrella of "City as a Computer" [6]. However, even in these areas, there is debate as to whether the approach to digitalisation adopted is the right one, and whether we are not, instead, espousing a technocratic vision that undermines its own objectives by naively seeking universal application.

City as a Living Organism: as opposed to the previous (and older) concept, describes the idea that a city is not reducible to the sum of its quantifiable components, and not even to the sum of its flows. Supporting doctrine comes from [8], in particular with reference to the idea of "Relational Ecosystems" and "Digital Urban Acupuncture (DUA)" as a study-intervention methodology. Also at the beginning of [4] it's made explicit: *Smarting the city is a complicated process due to the complexity of a city. The city is not an automated system that can be easily understood and predicted, but rather a living system that evolves every day through variations and developments of its physical constructs, economic and political activities, social and cultural settings, and ecological systems* (quoting [9]).

A decisive contribution comes from Courmont - Le Galès [10], where they recognize that there is a *contradiction intrinsèque entre le formalisme numérique et l'informalité qui caractérise l'urbanité*[4].

It is crucial to understand this aspect in order to be able to talk about the relationship between data and the city, taking into account in particular two factors:

a) the dynamism of the city: Les villes sont le théâtre du développement de nombreuses innovations numériques car elles sont le lieu des innovations, des échanges, de la création de richesse, de la dynamique des marchés du travail, de la mobilité sociale, de formes de démocratie, de fabrique sociale et d'interactions[5].

b) the criticalities of the city: Les villes présentent également de nombreuses dimensions problématiques pour la vie humaine, comme la ségrégation, les déchets, l'inégalité et l'isolement social, la dégradation de l'environnement, la pollution, la violence, la congestion, et les conflits entre groupes[6]. In the light of this (p. 8), Le numérique peut contribuer a refléter, minorer ou amplifier ces processus. Les technologies sont tout à la fois facteur d'inclusion et d'exclusion sociales[7].

The challenge it comes to (p. 8): given the scale of these issues, finding (digital?) forms of collective action and governance that contribute to solving these problems is a crucial challenge in Europe and in the world's major cities. The theme is taken up again on p. 21, in relation to the difficulties of Sidewalk Labs (Toronto), promoted by Google in Canada, and to comment on the so called "Villes nouvelles privées high-tech", promoted by various actors as examples of smart cities intended only for elite groups of the population, focused on maximum efficiency and, therefore, devoid of politics.

[4]Translated by the Author: "intrinsic contradiction between digital formalism and the informality that characterises urbanity".

[5]Translated by the Author: "Cities are the stage for the development of many digital innovations because they are the place for innovations, exchanges, wealth creation, labour market dynamics, social mobility, forms of democracy, social fabric and interactions".

[6]Translated by the Author: "Cities also present many problematic dimensions for human life, such as segregation, waste, inequality and social isolation, environmental degradation, pollution, violence, congestion, and intergroup conflict".

[7]Translated by the Author: "Digital technology can help to reflect, undermine or amplify these processes. Technologies are both a factor of social inclusion and exclusion".

Due to the considerations made, it seems to emerge clearly as:

some parts of the (Smart) City can be considered "as a Computer", like the basic functioning of energy, traffic and waste flows;

other parts of the (Smart) City must be considered "as a Living Organism", like the relationship between different districts and areas, or the complex effect that is recalled under the name of "gentrification".

The debate, therefore, seems to be unsolvable, or too much influenced by the point-of-view of the Author(s).

With a Proactive law approach, that will be reported shortly, however, it is proposed - for the purposes of this analysis - to attempt a redefinition of the schemes with which we evaluate smart cities projects, and, in particular, the DTC projects that interest us. This will be done according to the new proposed opposition between "Real-Time DTC" and "Simulation DTC".

2 METHODOLOGY

In conducting this analysis, it has to be firstly remembered the power of shaping legal framework to obtain practical results. Citing Richard A. Posner in [11] about the concept of a "virtuous cycle", even modest investments in legal reform can lead to increased economic growth, which in turn generates more resources for further legal reforms. This idea could apply to different areas and fields (with results not necessarily in terms of more resources, but for example in a better quality of life), such as Human rights, sustainability, innovation, public health and more. A better understanding of a legal framework, and modest investments in adjusting it, could lead to positive feedback loops and significant long-term benefits across a range of aspects.

Secondly, the EU digital approach has been taken into account. In particular, as analyzed by Gianluca Fasano (CNR) for Federalismi.it [12], we need to move away from the old and so-called prosthetic conception [13], which recognizes artificial intelligence as the task of expanding the boundaries of human cognition. Instead, to set our debate in a true human-centric vision, with the commitment to put human, with his needs, his values and his rights, at the center of technological innovation [12]. At European level, write Fasano, foundation elements are the strategy for the development of reliable AI [14], in particular in the Communication "Building Trust in Human-Centric Artificial Intelligence"[15], with which the European Commission has implemented the fundamental requirements established in the Ethical Guidelines for Trustworthy Artificial Intelligence prepared by the Group of Senior Experts on AI. More recently, the human-centric approach has been placed at the basis of the "European Declaration on Digital Rights and Principles for the Digital Decade", in which, once again, the regulator is called upon to balance the need for protection of the person with the strong push towards the promotion of the digital economy [15].

The starting point is the recognition that the direction of the implementation and evolution of DTCs in Europe will necessarily have to conform to this concept (human-centric vision) and not deviate significantly from it, except to expose oneself to possible criticism by jurisprudence or to reproach and rejection by public opinion.

Starting from this, it seems appropriate to refer to a Proactive Law approach, as defined by Seipel in his works [16].

In particular, this approach is necessary since:

we are exploring a highly technological territory, with components from 3D scanning to Information Models, from the 5G to the data servers.

we are exploring a highly hypothetical territory, which presents significant discrepancies between what is present in theory, or in announcements, and what are concrete implementations.

we are in a strongly interdisciplinary context, since a wide range of disciplines is touched by the implementation of a DTC and all its components (unlike the IoT sector, where the idea of the digital twin comes from).

For this reason, a proactive law analysis allows to outline future scenarios and provide ideas and observations for the application of the Law (existing or drafted or desired) before the technological implementation produces "high impact effects".

As Seipel himself reconstructs, Proactive Law is part of the "Legal Informatics" (in turn originated – at least in some forms– by the Philosophy of Law), since: in legal informatics, writes Seipel, *the pro-active perspective on law has always been present, in fact one can say that it constitutes one of the pillars of legal informatics. Thus, early studies of adaptation of legal rules to automation appeared already in the 1960s and advanced attempts to develop a legal theory of databases were made during the 1970s. One of the focal points of my own doctoral thesis in 1977 was 'legal system management' with the double meaning of 'legal management of information systems' and 'management of legal information systems'. Both tasks are closely linked to proactive thinking* [16].

For this reason, this methodology seems the most adequate to be considered as a starting point for the legal analysis. In particular, starting the debate from the contrast between "Real-Time DTC" and "Simulation DTC" could contribute to a better conceptualization of future scenarios.

3 "REAL-TIME DTC" AND "SIMULATION DTC"

The idea to analyze and frame DTC projects according to the proposed dichotomy between "Real-Time DTC" and "Simulation DTC" comes from the text "Expérimentations urbaines" [17], in the book "Governer la ville numerique" [18]. The chapter cites two examples: Virtual Singapore (a DTC as the most advanced at this time) and MuniMobile (San Francisco) (an example of Real-Time Democracy).

The key to understanding proposed by the authors to highlight and analyze the characteristics of urban digitization projects is that of the "Expérimentations urbaines" and "L'expérimentation comme catégorie analytique". The authors write [18]: *Cette expression désigne des situations de la vie urbaine où sont déployés des expérimentations, tests ou pilotes qui engagent la nature de la ville elle-même*[8]. The aim is a *nouvelle compréhension de la façon d'agir sur la ville en ciblant des questions centrales pour y apporter des solutions*[9].

According to the Authors later in the text (pag. 54-55), the definition of "experiments" underlines how expressly the projects are intended to experiment, to try solutions also organizational, to *produire de nouvelles connaissances qui restent, au moins en partie, incertaines et liées à des démonstrations publiques*. So, *toute expérimentation urbaine, déployée dans un lieu physique ou à travers une technologie de simulation et de modélisation numérique, contient, plus ou moins explicitement, une vision singulière du futur incluant un réordonnancement (social, economique, politique) des espaces urbains*.

According to the Authors [19], the literature on experimental urbanism invites us to analyze experimentations as empirical and theoretical entry points to study the transformations of contemporary urban spaces. The vocabulary of experimentation has become an omnipresent trope in the discourse of contemporary urbanism. They mention the term "test-bedded" in this regard. The simulated environment can be used to test "possible" scenarios or to virtually explore the consequences of a particular situation.

They point out the dual nature of these experiments:

on the one hand, they are intended to carry out experiments on urban infrastructures and environments, which can also impact citizens;

on the other hand, they are themselves experiments that bring into play the ability of these platforms to intervene on the urban. For example, the specific traffic management app (e.g. MuniMobile in San Francisco) is an urban experimentation, but the possibility that you can use an app to manage traffic is, in turn, another experiment.

3.1 Real-time DTC Applications

The DTC applications that we have identified as the first type are applications that interact with current reality and, in particular, receive real-time data. These applications of DTC focus on the ability to optimize the performance of the city as a policy tool. Taking the example of San Francisco, the Authors indicate [20] how the whole order lends itself to making the ajustement *en temps réel the central tâche de la gouvernance urbaine*[10].

This type of DTC can be configured as a "digital shadow", or as a real "digital twin" (according to the tripartition illustrated in paragraph 1), since the data flow is certainly coming from the physical to the digital level, and a direct transfer from digital to physical can also optionally be implemented.

In the first case, it will be necessary to pay special attention to the issue of data collection.

In addition to this, where there is a real "digital twin city", attention must also be paid to the transfer of data from the digital to the physical level, according to the methods implemented on a case-by-case basis. This digital intervention on the city represents something futuristic, but it's not far from becoming a true reality on a large scale and it has to be compliant with the entire law-corpus of our States, not only relying on "sandboxes" and "pilot tests". For example, it has to be fully compliant with Data Protection (GDPR), which is not merely an administrative exercise but is the way in which we "take care" of our societies [21]. Added to this are the (future) AI and Data Governance regulations, with their specific provisions, in particular those prohibiting public credit scoring systems.

3.1.1 Real-Time DTC and Human in the loop. For this kind of DTC, it is necessary to pay attention to maintaining the presence of the human in the system (so-called human in the loop [22]).

[8]Translated by the Author: "This expression refers to situations in urban life where experiments, tests or pilots are deployed that engage the nature of the city itself".
[9]Translated by the Author: "new understanding of how to act on the city by targeting core issues for solutions".
[10]Translated by the Author: "in real-time the central task of urban governance".

The theme, often addressed with reference to maintaining the human-in-the-loop in individual decision-making, acquires a further connotation and significance when it comes to a community, for example in the case of the city and the city administration. It therefore becomes essential to keep the politics in the loop, because only in this way we can have a democratic control. These reflections cross those of Luciano Floridi, who devoted important words to this point to analyze the forms of democratic control in the information age. As Floridi writes [23], distortions to the democratic system (the system in which the people control governance) can occur both when governance is identified with the people ("populism"), and when governance controls the people to such an extent that it has overturned the function of control ("corporate populism").

As far as we are concerned here, we can see in the Real-Time DTC precisely the possibility that it constitutes a socio-technical system of control over the city, operated not only by the administration, but also - hypothetically - by the producer of the computer set that supports and constitutes the DTC. These draft scenarios suggest particular caution in defining and regulating true Real-Time DTC.

To complicate the sociotechnical picture that we are describing in potential terms, we need to consider the necessity to maintain a democratic control over the administration. While it's possible to allocate responsibility to those who authorise the system, AI will not be completely under control by Public Authorities. The topic is intensively debated (see for an EU agenda [24]), but at the time of writing, no software-house or software-producer is "fully taking responsibility" for its own software.

3.1.2 Impossibility of verification. In this type of DTC there are also other problems concerning how to evaluate the intervention. As mentioned, this aims to solve critical situations in real-time and adapt the functioning of the city to meet changing needs. But how to verify the usefulness and effectiveness of the intervention? To explain the criticalities and attempt a first analysis, it is necessary to break down the question into further sub-questions.

Different DTC projects on the same city: Can it be possible?

One possible answer, often presented by the producers of these technologies, is that the connection with reality would immediately show which model is working better. The answer is, however, questionable, since it falls into the problem of the self-fulfilling prophecy of the smart city. A possible way out may come from the fact that the construction of a DTC requires the intervention of so many actors that it eliminates space for possible competing projects, making collaboration somewhat necessary. However, the fact we have a plethora of actors involved is not a sufficient condition to define the DTC as "democratic".

The possibility to have different models on the same environment could constitute a hypothesis not to be discarded a priori as a device for the administration of public affairs, since it would be possible to give policymakers more range of "space" for decision making (imagine, for example, what will happen if the only model available is "wrong" and is misunderstanding the reality: policymakers would take a poor decision, but claiming to have been forced. The Law must find a solution to this problem of accountability).

Furthermore, how to verify the usefulness and effectiveness of the intervention if the intervention itself modifies the conditions of the environment from which the DTC takes the data?

This is evident by drawing a parallel with the world of scientific research, and in particular of research laboratories. When a technology or experimentation operates in real-time in the city and in reality, the problem arises of how to "verify/falsify" the result, and therefore the action operated by the technology or experimentation. According to the Authors [25], it is important to note that they try to adopt a scientific approach, but with an important difference. Contrary to the closed and controlled environment of scientific laboratories, urban laboratories are themselves part of the experimentation that is tested, being the "laboratory" (the city), part of experimentation and experimentation itself.

It is, for all intents and purposes, an "experiment" that in practice would like to be as scientific as possible, but that profoundly modifies the "laboratory" in which it unfolds, the city. The risk to fulfill your expectations is evident.

So, how can you control your prediction if you alter the reality to follow the prediction? How to benchmark?

Firstly, it has to be reaffirmed that no software should be able to produce a consequence that a human cannot stop in advance and evaluate. In this, is necessary to keep a possibility for human decision-makers to depart from the suggestions of the model.

In the case of a true real-time DTC, however, what we could define as "self-fulfilling prophecy of the smart city" is taken to the extreme. This is the axiom that the Smart City will be realized thanks to digitization. For some [1][25], the "digital twin city" is likely to be the emblem of the highest self-fulfilling prophecy, since adaptation takes place based on real-time information and forecasts. According to Courmont and Le Galès [26], this is possible starting from the ideal of ubiquitous computing, made possible by certain conditions like *la miniaturisation des capteurs*, *la diminution des coûts de stockage, l'augmentation considérable de la puissance de calcul et l'expansions des réseaux de communication organisés, Régulés, parfois financés par les autorités publiques*[11].

Added to this are the recent transformations of capitalism, which emphasize data as creators of value, or even currencies.

Concordant doctrine on those points can be found around the expression of "enveloping the city" or the entire world, as in [27] and [28].

This has also led to the massive entry of private actors into the governance of the city. In [29], the Authors write: *Le langage des "solutions" renvoie ici à des problèmes qui ne sont pas encore identifiés, mais qui pourraient l'être par l'intervention d'acteurs ayant une expertise en matière de logement, de transport, de santé, etc.*[12] , which obviously begs the question of what the purpose of the intervention is and, in particular, how uncertain the burden of proof is when it comes to public policy: who has to find the solution is easy to determine, but who is to identify the problem?

3.1.3 Precautionary Principle. Those considerations, considering the uncertainties related to software liabilities, in the light of potential harm to democracy and governance, suggest evaluating

[11]Translated by the Author: "the miniaturisation of sensors, the decrease in storage costs, the considerable increase in computing power and the expansion of organised, regulated and sometimes publicly funded communication networks".

[12]Translated by the Author: "The language of 'solutions' here refers to problems that are not yet identified, but which could be identified through the intervention of actors with expertise in housing, transport, health, etc".

the problem from a Proactive Approach, trying to anticipate the implementation of the technology and mitigate possible risks.

As it stands, DTC risks transforming the surveillance problem of the traditional smart city (in which, citizens themselves unwittingly participate in their own surveillance [30]) into an even more complex problem, in which massive interaction with software risks triggering alterations in people's behaviour to obtain credits, discounts and administrative "rights".

As described, the impossibility of verification of results poses a decisive point.

To find solutions to those criticalities, it seems necessary to develop anything that can "keep the human in the loop".

Another help in this sense comes from the so-called "Precautionary principle", defined as the principle which enables decision-makers to adopt precautionary measures when scientific evidence about an environmental or human health hazard is uncertain and the stakes are high [31]. First emerged during the 1970s, it has since been enshrined in a number of international treaties on the environment, in the Treaty on the Functioning of the European Union and the national legislation of certain Member States. While not forgetting the difficulties in applying this principle, it can certainly be considered a starting point in the regulation of Real-Time DTC, for the questions described before.

The application of the precautionary principle presents many opportunities as well as challenges, and it is closely linked to governance in three aspects: risk governance, science-policy interfaces and the link between precaution and innovation. For these reasons, it deserves to be considered in spite of the criticism pertaining to its lack of scientificity, and be incorporated in government policies, aiming to implement participation, respect for rights, solidarity or address inequalities. In fact, even smart cities cannot be strictly considered a form of scientific governance, going to modify and destroy their own starting conditions, their own "laboratory".

3.2 Simulation DTC Applications

The above considerations for a Real-Time DTC could be overcome if a pure "Simulation DTC" is implemented. In this sense, a Digital Twin that is purely "virtual", with:

no direct data transfer from the digital to the physical (in other words, a "digital shadow");

room for human in the loop, and in particular for the politics and the public administration, on which a democratic control can be applied (mitigating the possibility for a "corporate populism");

possibility to analyse different scenarios and produce different outcomes, later to be implemented in the city if and only if democratically chosen;

more space for evaluating possible side effects of decisions, and effects on a medium-long term based.

However, also those types of DTC present problems.

It's necessary to understand their regulation, involving all the stakeholders in the city-context (even the hidden and silent ones, briefly highlighted by [32] with their "Grille de valutation" on "Expérimentations urbaines".

It's necessary to have a legal framework that encourages the "Expérimentations urbaines", as well as (the reviving of) the creation of ideas and concepts to be tested on the DTC, to keep it alive and not only a top-down proposal on the city. This framework has to allow citizens to participate in the DTC, proposing ideas, solutions and projects. The topic is not without problems, when it comes to taking decisions (democratically?) on the use of a vast amount of energy and resources necessary to run a DTC and simulate complex scenarios.

Additional questions arise on the data ownership or the infrastructure ownership of the DTC, since it is debatable that a "City Brain" (as described in [2]) can be owned only by a private company without a public ownership. Conditions for the existence of a software market, that can boost the experimentation purposes in special DTC sandboxes prior the adoption by the city, need to be set.

The scheme of the "Simulation DTC", however, also in light of the problems briefly highlighted, seems more effective response to the informality of the city, since the experiments - simulations are more easily allowed to respond, cope, not to harness the irreducible a fundamental dichotomy between digital data and urbanity.

4 CONCLUSIONS AND FURTHER RESEARCH

For the purposes of this analysis, we have briefly reconstructed the existing debate on DTC as an application of Smart cities, referring to the insoluble dichotomy between "City as a Computer" and "City as a Living Organism". This debate is proposed to be put aside – for the purposes of this work -, in favor of an analysis around the dichotomy between "Real-Time DTC" and "Simulation DTC".

It has been found that a "Real-Time DTC" could pose higher risks, when it comes to public life of a city, but also for the individual rights. On that, following a Proactive Approach to Law, the principle of the "human in the loop" and the "precautionary principle" are presented as possible solutions to be incorporated in public policies and laws on DTC. The presence of politics (such as "humans in the loop") prevents the possibility that a DTC result in a technological dependence of the public sector on private hardware and software. The public-private match is inevitable, but not the dependence of the public on the private sector, nor the risk of a "corporate populism" through a DTC.

It has been found that a "Simulation DTC", without a direct effect on the city's life, will pose less criticality and can be better used as an example of what a Digital Twin technology as to be to help policymakers and citizens in shaping the city in the XXI century.

From this starting point, it is possible to investigate other legal implications in order to compose a more complex and detailed "matrix" of possibilities, dealing with projects that do not resemble uniquely the black-and-white dichotomy proposed and used in this paper. As a note for further research, three points can be highlighted:

a) Establishing data governance policies and encouraging public participation: Digital Twin Cities rely heavily on data from various sources, which raises privacy concerns. At the same time, Digital Twin Cities should be developed with the participation of the public to ensure transparency and accountability. It could be argued that every DTC project will have to deal with a percentage of citizens refusing to participate in it, but it is also essential to establish data governance policies that regulate the collection, use, sharing, and

protection of data. This can be achieved through various engagement mechanisms, giving representation in the DTC to all the "data owners" involved.

b) Ensuring cybersecurity and addressing liability issues: Digital Twin Cities are vulnerable to cyber-attacks, like any other infrastructure which relies on the digital [33], which can result in significant consequences. Therefore, it is crucial to ensure the cybersecurity of the virtual model, including secure data storage, encryption, and access control. At the same time, Digital Twin Cities involve various stakeholders, including government agencies, private entities, and citizens. The need of cybersecurity, however, could not undermine the possibility to develop Open-source solutions and to have voluntary contributions to software ideation and development [34].

c) Fostering interoperability and establishing regulatory frameworks: Digital Twin Cities require interoperability between various systems and technologies, which can be a challenge. However, this interoperability does not have to be thought of exclusively inside the city perimeter: it must be with other cities in the same State and cannot lead to discrimination between who is in the city and who is outside.

In conclusion, from the analysis operated it emerged how Digital Twin Cities require *ad hoc* regulatory frameworks that define the legal boundaries and responsibilities of stakeholders involved in the development and use of the virtual model.

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