When the City Simulates Itself. Ethical Legitimacy in a Civic Digital Twin for Urban Access Regulation

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Abstract

This paper presents the industry case discussed at the workshop. It deliberately does not present a solution: it presents a problem and its facets, so that participants can work on it. The case concerns a Civic Digital Twin (CDT) used to support a municipal decision on urban access regulation, a policy family that includes low-emission zones, restricted-traffic zones and access fees. The twin simulates candidate policies before the council votes and keeps observing the city afterwards. The difficulty is ethical rather than technical. A city-wide emission reduction is an average, and averages hide the fact that the same policy is nearly free for a resident with a metro stop downstairs and expensive for one without alternatives. To make that asymmetry visible, the twin must carry people, their values and their structural vulnerabilities inside the model as first-class entities. Doing so raises questions the engineering literature does not answer: who decides which attributes of a person the model may see, what a simulation is entitled to settle on a citizen's behalf, and what obliges a city to reopen a decision the twin got wrong. After the case presentation, participants split into two parallel groups along Floridi's distinction between hard and soft ethics. **Group A (hard ethics)**: what must a municipality be able to demonstrate, and to whom, before a twin-supported decision counts as justified? **Group B (soft ethics)**: how do the differing values and lived vulnerabilities of citizens enter the twin as first-class concerns rather than as context? Both groups then return to the same artefact, the exemption rule, where their recommendations are expected to collide.

Keywords

Civic Digital Twin, urban access regulation, ethical impact, hard and soft ethics, social vulnerability, participatory governance, workshop case study

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1. Introduction

A digital twin is a virtual representation of a real-world subject or object that exchanges data continuously with its physical counterpart. Since Grieves' tripartite formulation of real space, virtual space and the data link between them [1], cities have been among the most enthusiastic adopters of the idiom. Urban Digital Twins (UDTs) are now a standard instrument of data-driven planning, and they carry a well-documented weakness: most deployments treat citizens as subjects of monitoring rather than as co-designers of the city they live in [2].

The *Civic* Digital Twin (CDT) is the response to that weakness. Articulated by Luca et al. around the Bologna initiative [3], it proposes an evolution of the UDT towards citizen-centric governance, in which the citizen is a prime actor inside the twin rather than a data point observed by it. The MoST unit at Fondazione Bruno Kessler develops the open modelling framework behind that initiative [4] and the scenario-based simulation machinery used to evaluate the impact of traffic regulations on complex mobility systems [5]. In parallel, the group at the University of L'Aquila works on ethics-aware autonomous systems: context-aware ethical negotiation [6], a reference architecture that treats ethical reasoning as a first-class architectural concern [7], and an ethics label documenting how a digital system

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affects human, societal and environmental values [8]. This case comes out of the ongoing attempt, by these groups together with DISI Bologna, to make a civic twin ethics-aware, and out of the questions that attempt keeps raising and failing to settle.

The platform and the initiative are real. The policy scenario used here is illustrative: it is constructed to be realistic and discussable in a workshop, and it does not represent an actual proposal of any municipal administration.

This document follows the case-brief genre of previous editions [9]. It states a problem, lays out its tensions and the parties who experience them differently, and stops there. The solutions are the participants' work.

2. Background

What the twin does today. The civic twin serves a recurring family of municipal decisions: whether, where and how to regulate vehicle access to a part of the city. Restricted-traffic zones, low-emission zones and access fees are the usual instruments, and they are typically justified by congestion and by binding air-quality obligations [10]. The twin's role is to make the future of a candidate policy inspectable before it is adopted. A scenario encodes one candidate configuration: the perimeter of the regulated area, the time window, the fee level, the exemption rules. Traffic-flow, modal-shift and emission models produce predicted outcomes, which are displayed at the council session where the policy is debated, so that administration, opposition and public argue from the same evidence base. After adoption, observations feed back, and the gap between predicted and observed becomes the basis for revision.

Why this is now in question. The twin has been a success as an instrument of technical argument: it disciplines a debate that used to be conducted on anecdote. The difficulty begins when the community asks the twin a question it was not built for. A city-wide emission reduction is an average, and averages are silent about distribution. Making the asymmetry visible means putting people, their values and their structural exposure to harm inside the model as first-class entities rather than as context [11, 12]. That is what turns an urban twin into a civic one. It is also what creates the problem this brief is about.

3. The Challenge

To show who bears the cost of a policy, the twin needs to know who is exposed. Exposure is not observable directly; it is constructed from indicators, in the tradition of the social vulnerability indices used in disaster management and public health [13, 14]: age, income, car dependence, care needs, distance to alternatives. Every one of those indicators is a choice about how a person may be seen by the institution that governs them, and none of those choices is technical.

At the same time the twin's status changes. As long as it answered technical questions, its outputs were arguments. Once it informs a binding decision, a predicted number acquires the authority of evidence, and the burden of argument shifts onto whoever disputes it.

3.1. The Decision on the Table

The city council must decide whether to introduce a working-day access fee for a designated central area, with the stated goal of reducing vehicular emissions there by 15% against the current baseline while preserving mobility access for residents with the fewest alternatives. Three candidates are on the table: keep the status quo; introduce a flat fee; or introduce the fee with reduced or waived rates for low-income residents and exemptions for care-related trips.

Three people, among many, will live with the result.

- **Maria**, 72, lives inside the perimeter and travels weekly to a hospital appointment across the city. There is a bus, but not at the hour her appointments are scheduled, and not with the walking

distance she can manage. She is car-dependent, and her dependence is invisible in any dataset the city currently holds.
- **A weekday commuter** from a peripheral municipality, on a low income, starting a shift at 5:30 a.m., when no public transport runs. For him the fee is not a nudge towards a different mode; there is no different mode.
- **A self-employed courier** whose margin per delivery is smaller than the daily fee, and whose employer is an algorithm that will not absorb it.

The exemption rule is where this case bites. It is the instrument through which fairness is actually delivered, and writing it requires the city to decide who counts as exposed, on what evidence, and for how long. Every candidate answer is defensible, and every candidate answer leaves someone out.

3.2. Key Tensions

1. **Evidence vs. legitimacy.** A simulation credible enough to inform a decision is credible enough to foreclose one. Who authorised a model to bound democratic deliberation, and what does dissent look like once the twin has spoken?
2. **Aggregate benefit vs. asymmetric burden.** The policy is justified by a city-wide gain; the cost is concentrated on those with the fewest alternatives. Both statements are true at once, and the twin reports either one depending on how the outcome is disaggregated. Who chooses the disaggregation?
3. **Visibility vs. dignity.** To protect the vulnerable, the city must first classify them. Being classified is not a neutral act: a municipal record of who is fragile is also an instrument of administrative control, and the people it describes did not ask for it.
4. **Compliance vs. justice.** The policy can satisfy every air-quality obligation, every procedural requirement and every emerging duty on public-sector AI [15], and still be unjust to Maria. Nothing in the twin notices this. What should?
5. **Responsiveness vs. contestability.** The twin closes its loop continuously: observe, re-predict, adjust. Contestation is slow and needs a fixed object. If the model that justified a decision has already been superseded twice by the time a citizen appeals, what exactly is being appealed?

3.3. Stakeholder Perspectives

1. **Residents and city users.** Want the air quality and the quiet streets, and want to keep reaching work, care and family. Those with the fewest alternatives carry the policy's cost and are the least represented in the consultations that shape it.
2. **Community and advocacy organisations.** District committees, associations representing older and disabled people, informal networks of delivery riders. They hold knowledge of local exposure that no index captures, and they are wary of a process in which that knowledge is replaced by a number.
3. **Municipal decision-makers and the council.** Need a defensible basis for a decision that will be contested politically and possibly in court. The twin gives them one. It also gives them something to hide behind, and they know it.
4. **Those who build and operate the twin.** Modellers, municipal IT, contracted vendors. Their choices about what the model can represent determine what the council is able to see, which makes a modelling decision a governance decision made in advance and without a mandate.
5. **Regulators and oversight bodies.** Air-quality obligations [10] and the emerging duties on AI systems used by public authorities [15] set the floor of what is permissible. They do not set the ceiling of what is right.

3.4. The Questions

The overarching question for the workshop is: *how should a civic digital twin represent citizens, their values and their structural vulnerabilities, so that simulation evidence strengthens rather than replaces democratic deliberation over a policy that burdens people unequally?*

Participants address it in two parallel groups, split along Floridi's distinction between *hard ethics*, the rules imposed by higher authority, and *soft ethics*, the individual preferences and values that vary across people and contexts [16].

Group A — Hard ethics: what the city owes. What must a municipality be able to demonstrate, and to whom, before a twin-supported decision counts as justified? Which duties should be codified inside the twin itself, and which must remain political judgment?

Group B — Soft ethics: what citizens value. How can the differing values and lived vulnerabilities of citizens enter the twin as first-class concerns rather than as context? What would it take for a resident to recognise their own situation in the model that decides about them?

3.5. Discussion Points

For Group A:

1. What is the minimum a city must be able to show to justify a twin-supported decision: which model, which data, which run, which alternatives were considered and rejected?
2. Compliance is not legitimacy. Where does the gap open in this case, and whose job is it to notice?
3. Should ethical constraints be encoded inside the twin, as conditions the simulation must respect, or kept outside it as political judgment? What is gained and lost either way?
4. When the prediction turns out to be wrong, the target missed or the exemption too narrow, what obliges the city to reopen the decision rather than quietly re-tune the model?
5. Who is answerable for a modelling choice that made a group invisible: the researcher, the vendor, or the councillor who used the result?

For Group B:

1. Which attributes of a person must the model carry for inequity to become visible, and which must it refuse to carry? Who decides, and how often is that decision revisited?
2. A vulnerability profile is constructed, not given. At what granularity, individual, household, group or district, is it both useful and defensible? What happens when a person disagrees with the profile the city has assigned them?
3. Values genuinely conflict here: Maria's access to care, a parent's clean air, a courier's livelihood. Can a twin represent a disagreement without prematurely resolving it into a weight?
4. What does meaningful participation look like when the object of negotiation is a predicted outcome rather than a lived experience? Who is in the room, and who is only in the dataset?
5. Second-order effects: does making vulnerability computable also make it a permanent category of administrative classification, and would the people so classified consent to it?

4. Workshop Format and Expected Outcomes

The session runs in three phases. The case is presented in plenary and opened for clarification. Participants then split into the two groups above, each with a facilitator, working for roughly an hour on their guiding question and discussion points. Each group is asked to produce three things rather than a solution: the assumptions it had to make in order to proceed, a prioritised set of concerns, and at least one concrete intervention together with an honest statement of what that intervention costs.

The third phase brings both groups back to the same artefact, the exemption rule, and asks them to compare recommendations. The design of the session anticipates that they will conflict. Group A

is likely to argue for criteria that are explicit, uniform and auditable, since those are the properties that make a decision defensible to a court, an auditor or an opposition. Group B is likely to argue for representations of value that are plural, contextual and revisable, since those are the properties that let Maria's situation register at all. Uniformity and contextuality cannot both be maximised in the same rule.

The valuable output of the session is therefore not consensus but a catalogue of these conflicts, stated precisely enough to be worked on: which trade-offs are genuine and must be decided politically, which are artefacts of how we currently build such systems and could be engineered away, and which are simply unexplored. That catalogue is the input to the follow-on research, and it is what the organisers will collate and share with participants after the workshop.

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Declaration on Generative AI

During the preparation of this work, the author(s) used Claude (Anthropic) to improve writing style. After using this tool, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the publication's content.

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