Case Study Report

'Rethinking' digital twins and building alternatives for smart city planning in Dublin

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Abstract

Digital tools, including 3D spatial media, have existed for almost three decades. but they are gaining popularity with the emerging yet vague concept of Urban Digital Twin (UDT), believed to contribute to smart cities and resilient urban futures. While UDTs can visualise a multitude of datasets in an integrated, interactive, and comprehensive 'realistic looking' way, there are emerging structural and cultural challenges in their adoption within public sector planning. This case study explores these challenges within the context of Smart Dublin – an initiative involving the four Dublin Local Authorities, through an embedded research framework within an industry collaborative project between ADAPT Research Centre and Dublin City Council. The project aims at the ethical development and deployment of UDTs for territorial planning while understanding the barriers, opportunities and limitations for the largest Dublin Local Authority and evaluating alternative approaches to support participatory governance, informed decision-making, and awareness among urban planners working in a 'virtual' environment. It also introduces a transnational European project 'Twin4Resilience' with Dublin as one of the pilot actions aiming for a wider uptake of UDTs for data-driven urban decision-making. The lessons learnt will be incorporated into the broader digital twin strategy of the council.

Keywords

Urban Digital Twins, Territorial Planning, Smart Cities, Decision-making, Active Travel, Community Engagement

1. Introduction

In the past, since the 1980s, to support a spatially augmented approach to planning, digital tools including computer-aided design, 3D modelling, and GIS, have existed (Kitchin et al., 2021). However, today, global attention is shifting to an intelligent geospatial tool – *the Urban Digital Twin (UDT).* This study is from an embedded research collaboration between ADAPT Research Ireland Centre (a government-funded multi-institutional, multidisciplinary research centre) and Dublin City Council (DCC) (Dhingra and Kerr, 2024). The outcomes of our project contribute to the discussion on challenges and opportunities for implementing UDTs by Dublin local authorities for city planning, operations and management. This is backed up by the need for democratic governance processes and a 'human-in-the-loop' data-driven ethical decision-making approach.

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UDTs are defined as virtual replica models of physical places, assets and processes developed through the integration of large datasets in a single platform. Most of this data, if near-real-time, enables data processing and analysis through cloud computing and live feeds. A digital twin can enable a seamless way of working with multiple urban themes at once, which enables multistakeholder engagement to resolve the multidimensional challenges of our urban environment (Ziehl et al., 2023). However, there is a risk that, just like the 'smart city' concept, UDT can be reduced to a mere technology solution and not a long-term approach to innovative public sector planning (Nochta et al., 2021). This paper assesses structural, institutional and cultural challenges within an Irish public sector environment and proposes a conceptual approach to ethically implement UDTs.

Our approach is positioned within the current policy landscape of the European Union (EU) as the concept is significant in terms of digital twin initiatives such as the flagship Destination Earth[1] project for building a digital twin of Earth, the (Urban) Local Digital Twin (LDT) Toolbox[2] , project DUET (Digital Urban European Twins[3]) and the EDIC (European Digital Infrastructure Consortium[4]) initiative. Our research team seeks to unlock the potential of UDTs for urban planning, stakeholder collaboration and engagement by closely linking with challenges faced during implementation of use-cases with the key thematic areas at DCC smart city unit. We intend to address some of the urban challenges and improve public service delivery as well as support participatory governance, data-informed decision-making, and awareness-raising among city planners.

2. State of the art

2.1. Urban Digital Twin (UDT)

The literature review of 'digital twin' concept shows exponential growth, but mostly in areas of product lifecycle management, manufacturing and aerospace industries and operational and engineering solutions (Crespi et al., 2023; Syed Abdul Rahman et al., 2024). Cities on the contrary are complex ecosystems of built environment, people, their political, institutional, socio-economic and cultural contexts. Most of the time, private companies are hired for UDT services, but it is the public sector organizations who are responsible for day-to-day city operations (Deren et al., 2021; Ferré-Bigorra et al., 2022).

UDT research is still nascent and evolving and therefore needs an innovative approach tailored to a given city's needs, challenges and opportunities (Ziehl et al., 2023). There are a few already existing examples of UDTs as the ones highlighted by Bermúdez González et al. (2023), Dembski et al. (2020), Liu et al. (2023) and Park et al. (2023), however when distinguishing between digital 3D model or City Information Model from digital twins, an intermediary stage known as 'digital shadow' signifies information transfer from the physical to the virtual world through live data feed (Botín-Sanabria et al., 2022). A UDT, on the contrary, pivots towards 'platform urbanism' (Barns, 2019; Sadowski, 2020) serving as a unified platform for historical and real-time urban data to support advanced urban analytics, predictive simulation, near real-time visualisation and manifest back from virtual to physical dimension as shown in Figure 1**Error! Reference source not found.** (Fernandez et al., 2024). This interaction allows a UDT to serve as a 'living replica' throughout the project lifecycle, leverage real-time data insights, and simulate future scenarios, while also acting as 'virtual public spaces' for the public to interact with their cities (Cureton and Hartley, 2023; Truu et al., 2021; Ye et al., 2023).

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[1] About Destination Earth - Destination Earth
[2] Procurement for the development of the Local Digital Twins toolbox | Shaping Europe's digital future
[3] Home | digital urban european twins
[4] European Digital Infrastructure Consortium (EDIC) | Shaping Europe's digital future

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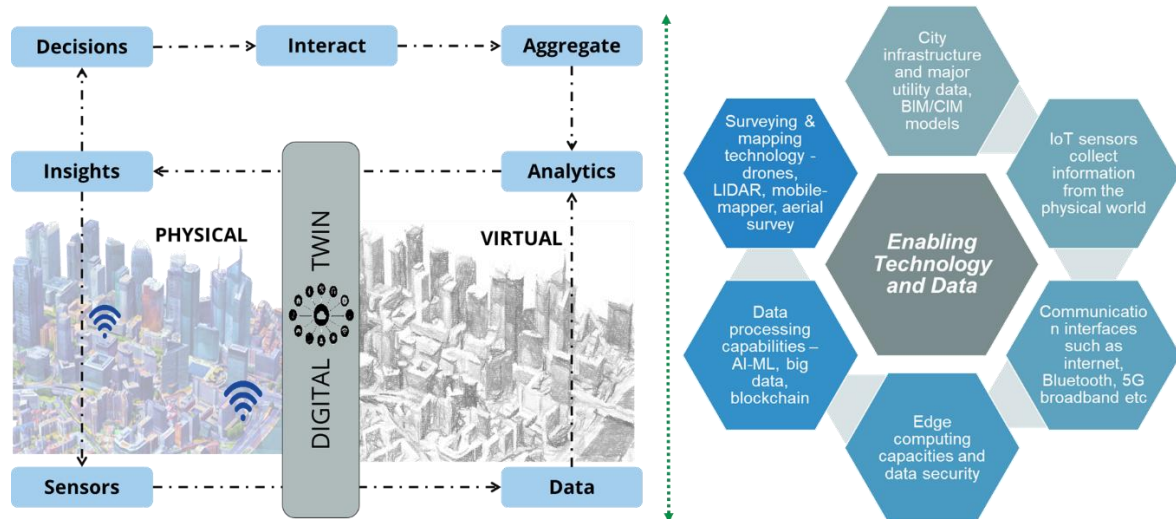8-12 OCTOBER 2024 | SIENA | ITALY

Figure 1: Bidirectional UDT and Underlying Technology. Source: Authors.

2.2.   UDT examples

The novelty of the digital twin concept is such that it can transform physical assets into programmable entities with clear analytics of major features in a targeted environment and conditions (Crespi et al., 2023). Other suggested advantages of UDTs delivery, include risk-aversive workflow optimization, support public sector planning and decision-making (Botín-Sanabria et al., 2022). To demonstrate UDTs in action, we present some examples in this section.

The first example (Figure 2) focuses on a climate-resilient housing project funded by the Public Sector Innovation Fund, with IES Pvt Ltd and DCC. A digital twin model was created for social housing stock at Dominic Street in Dublin, originally built in 1960. The model aimed to support reduction of carbon emissions and housing delivery targets of DCC. It calculates whole-life carbon impact in terms of building energy usage and renovating costs considering building lifecycle (Integrated Environmental Solutions Ltd., 2022).

Figure 2: UDT example 1 - Climate Resilient Housing. Source: IES Ltd.

The second example (Figure 3) shows a community-design intervention to address socio-spatial issues of a Dutch neighbourhood in Eindhoven using workshops and virtual reality tools (Najafi et al., 2023). The approach was rated as highly satisfactory by local residents, indicating an immersive UDT interface is effective for urban co-design exercise.

Figure 3: UDT example 2 - Community Design. Source: (Najafi et al., 2023).

The third example (Figure 4) proposed a co-creative planning layer in UDT technical architecture through an interactive gaming environment for urban design (Kavouras et al., 2023). Such creative engagement processes using UDTs show possibility for more dynamic, inclusive and responsive solutions to community needs. These examples also illustrate how UDTs can be employed for different levels and forms of community engagement – more small scale and active at the beginning of projects and in the design phase, while more passive and larger scale during the deployment of projects and monitoring phase – but all implemented within an ethical and rights driven approach.
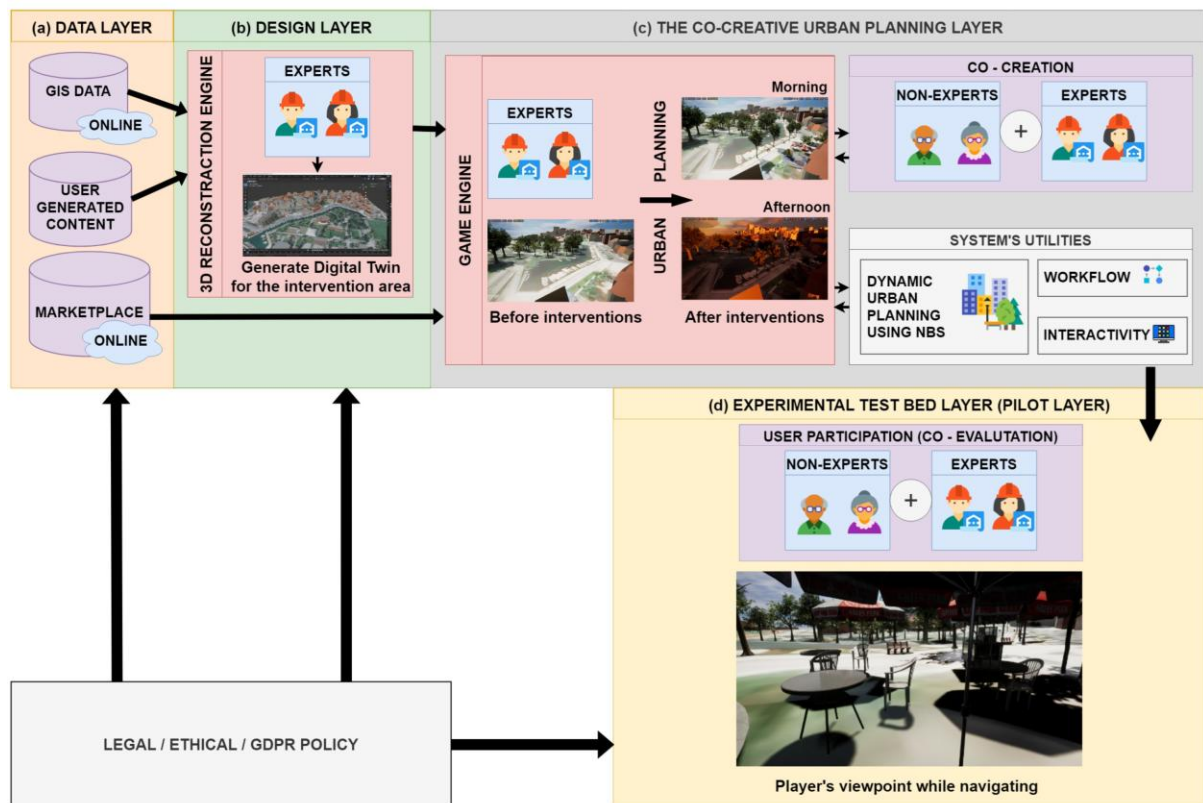
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Figure 4: UDT example 3 - Co-creation. Source: (Kavouras et al., 2023).

3. Smart Dublin case study

UDTs face many challenges with public sector lacking computational and technical resources (Ferré-Bigorra et al., 2022; Kitchin et al., 2021). Other aspects which need investigation while implementing a UDT project are related to defining the scale and scope of such interventions, ownership issues and operation manuals for envisaged functionalities, developing data governance guidelines, using FAIR and high-quality open datasets, and building a secure system (Barcik et al., 2023; Quek et al., 2023; Ye et al., 2023).

This case study is based within the Smart City unit of DCC, which uses smart districts as testbeds for developing and deploying emerging technology in a strategic manner, aligning with the local urban challenges and national policy framework (Dhingra and Kerr, 2024). Recent policies, such as the EU AI Act, Interoperable Europe Act, and Data Governance Act, highlight the importance of developing and deploying UDTs multi-thematic and multi-stakeholder approach to preserve democratic values and mitigate high risks (Figure 5).
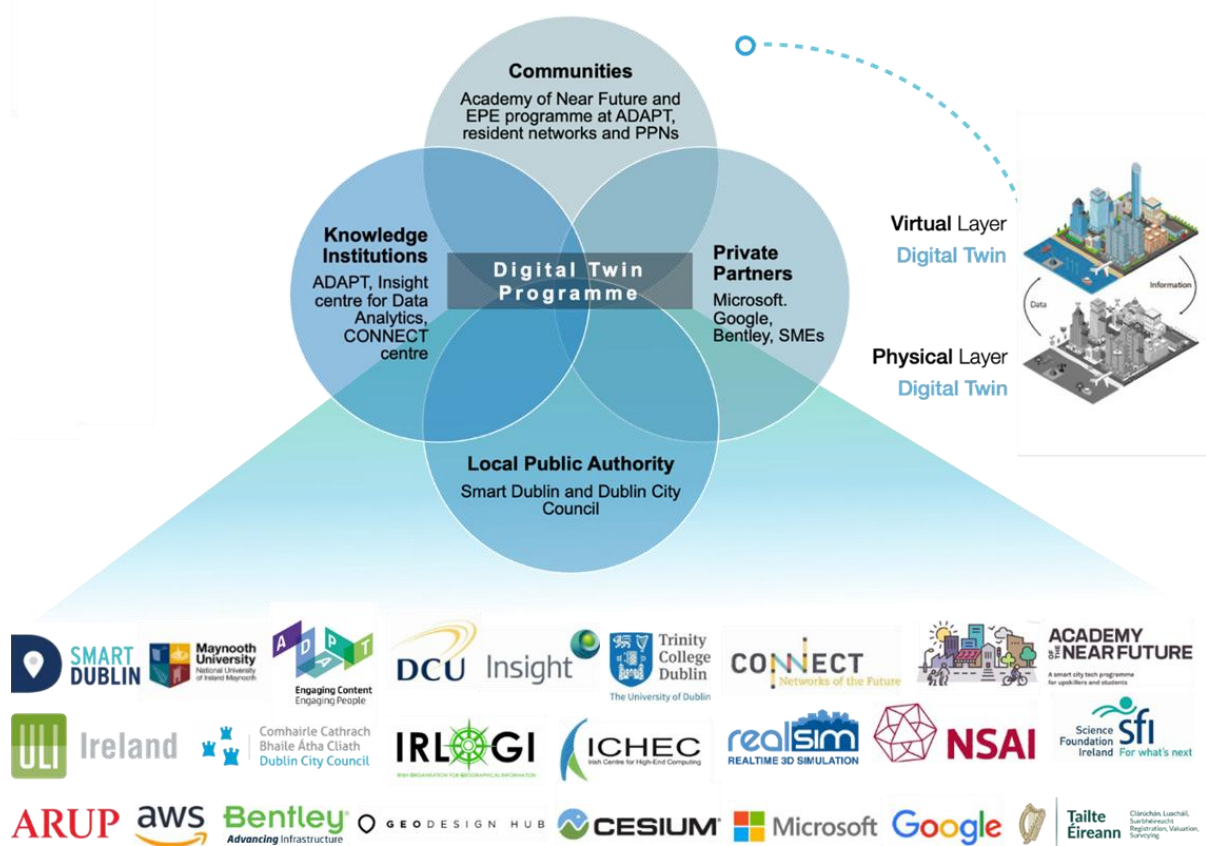
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Figure 5: UDT Programme - DCC. Source: Authors.

4. Rethinking 'Urban Digital Twins'

At DCC, existing UDT projects are 3D Docklands model, a university-based Smart DCU digital twin, and other bespoke approaches for emergency response, tourism etc. (Dhingra and Kerr, 2024; Fernandez et al., 2024). This industry-academia project intentionally moves away from a technocentric to an integrated, user-centric, and ethical process-oriented mindset. It is also based on prior work that found that a realistic-looking visual interface is critical for engagement via UDTs (Ferré-Bigorra et al., 2022).

Besides UDT enabling technology such as urban sensors, 5G network, and cloud computation, non-technical enablers include awareness to adopt interoperable standards, a compliant institutional data governance framework, and regular capacity building of local authority staff. Our conceptual approach shown in Figure 6, highlights data, platform and people at the core of any UDT project while constant alignment with ethics, governance, engagement and impact assessment. This conceptual approach intends to include humans, organisations and their abilities to implement and sustain a digital twin programme while safeguarding society's critical interests, optimal resource management and compliance with EU law and policies.
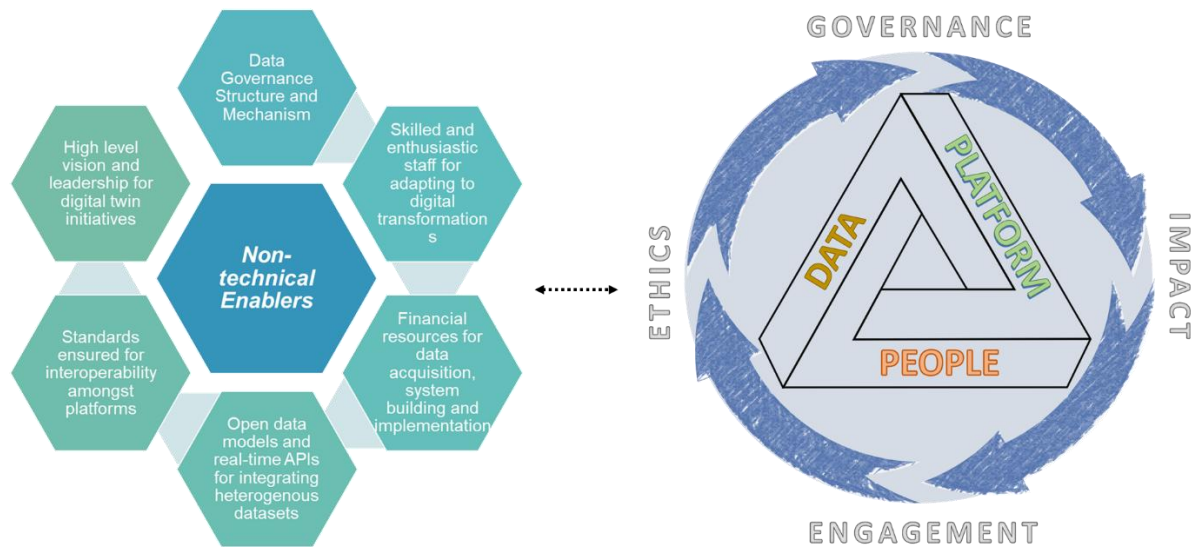
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Figure 6: Proposed approach for UDTs. Source: Authors

5. Project 'Twin4Resilience' (T4R)

Twin4Resilience[5] (T4R) is a European project from 2024 to 2027 and aims to enhance adoption of UDTs by public bodies for resilient territorial planning through four co-created frameworks as shown in Figure 7– technical design, governance, ethics-inclusion-democratisation and training. DCC's proposed pilot action focuses on two use cases – (i) territorial planning: visualize future urban projects in a virtual city-like environment and, (ii) active travel: assess the impact of new cycling and walking infrastructure. The first use case is achieved through publicly procured 3D-modelling services and the second use case leverages partnerships with nationally funded research centres.

Figure 7: Joint T4R strategy for pilot actions. Source: Authors.

Active travel, similar to digital twins, is multidimensional cutting across domains of urban mobility, climate and environment, community development, etc. Since 2020, there's been over USD 1 billion[6] invested in active travel projects across Ireland with DCC alone targeting a city-wide network of 314 kilometres of cycle paths by 2031. Two pilot routes viz. Clontarf to City Centre[7] and Kilmainham to Thomas Street[8] offer a

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[5] https://t4r.nweurope.eu
[6] Dublin is not just counting bicycles | Partnership for Healthy Cities
[7] Clontarf to City Centre Project | Dublin City Council
[8] Project Overview and Design Information | Dublin City Council

thematic template to assess the impact of these schemes and their contribution to environmental, and public health goals in Dublin. A series of dedicated stakeholder meetings and surveys were carried out to identify and subsequently prioritise key performance indicators and outcomes. This approach departed from the previous technology-led approach and emphasised a clear understanding of challenges and public needs (Cardullo and Kitchin, 2018). A regional Smart Dublin dashboard to show active travel routes is shown in Figure 8 and will be iterated as a digital twin engagement tool.
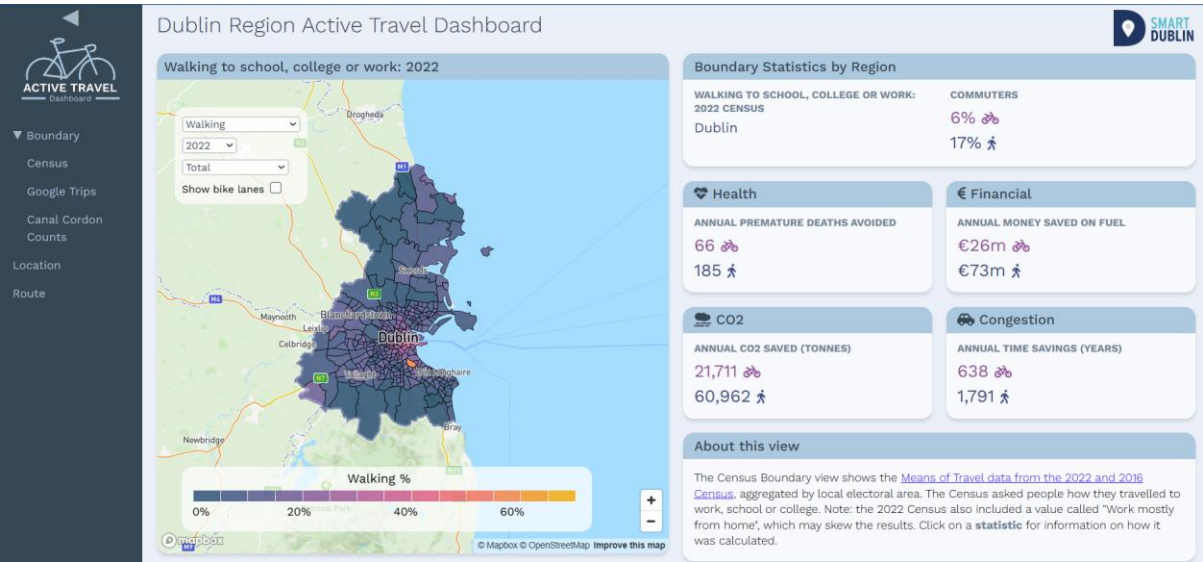

Figure 8: Active Travel Regional Dashboard. Source: Smart Dublin (2024).

6. Way Forward

This study gives an overview of Dublin's ongoing projects researching and implementing UDTs and throws insights into the practical barriers, issues and best practices for fostering participatory governance of urban planning in a digitally transformed environment. While many public sector applications of UDTs are still uncharted, emerging regulatory and multilateral governance frameworks are increasingly prioritising human-centredness, public values and fundamental rights (Muench et al., 2022; Ye et al., 2023). Although legislated responsibility may rest within different levels of local government, all actors (both institutional and non-institutional) must sufficiently enable the democratisation of urban digital twins.

Our research recognises that UDTs may serve as a vehicle to explore the engagement practices which collectively, could significantly enable and scale, impacts for interconnected climate and sustainable urban development determinants. Such data-driven approaches can potentially augment spatial representation and contribute substantially to people-centred planning systems, resilient urban futures, and better decision-making. There is a need to address potential barriers (e.g. proprietary software, lack of technical skillset amongst local authority staff and digital literacy of the general public, traditional mindset, cost of technologies etc.) by adopting a multistakeholder approach that is led by transparent governance, open standards, fundamental human rights and local social and context.

7. Acknowledgements

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