Citiverse Initiative
Global Initiative on Virtual Worlds and AI – Discovering the Citiverse

Citiverse Use Case Taxonomy: Urban Planning, Placemaking and Infrastructure

Foreword

This publication was developed within the framework of the Global Initiative on Virtual Worlds and AI – *Discovering the Citiverse*, which is a global multistakeholder platform launched by the International Telecommunication Union (ITU), the United Nations International Computing Centre (UNICC), and Digital Dubai, and supported by more than 70 international partners.

The Initiative aims to shape a future where AI-powered virtual worlds are inclusive, trusted, and interoperable. By connecting people, cities, and technologies, it empowers meaningful progress through AI-powered virtual worlds.

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Disclaimers

The opinions expressed in this publication are those of the authors and do not necessarily represent the views of their respective organizations, Executive Committee members or Steering Committee members of the Initiative. The findings presented in this report are based on a comprehensive review of existing literature and voluntary written contributions submitted by a diverse range of stakeholders.

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Abbreviations and acronyms

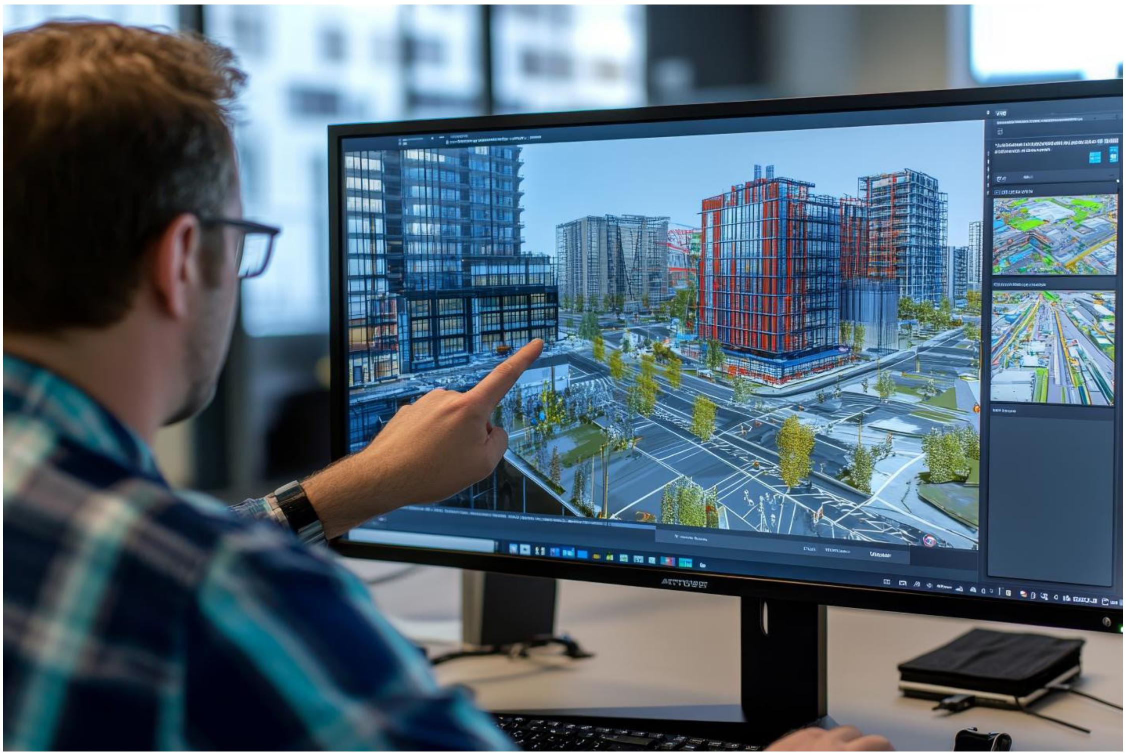
AI	Artificial intelligence
API	Application programming interface
AR	Augmented reality
BIM	Building information modelling
CCTV	Closed-circuit television
ESG	Environmental, social and governance
GAI	Generative artificial intelligence
GenAI	Generative artificial intelligence
GIS	Geographic information system
GPS	Global positioning system
ICT	Information and communication technology
IoT	Internet of Things
MR	Mixed reality
MVP	Minimum viable product
NBS	Nature-based solutions
NGO	Non-governmental organization
NUAR	National Underground Asset Register
ROI	Return on investment
SDG	Sustainable Development Goal
VR	Virtual reality
XR	Extended reality

1 Introduction

This report is part of a series produced under the Use Case Identification Track of the Global Initiative on Virtual Worlds and AI – *Discovering the Citiverse*. To make the taxonomy more accessible and user-friendly, the material has been presented as one overarching report and five thematic reports.

This thematic report focuses on urban planning, place making and infrastructure. It includes the overall taxonomy for reference, a thematic overview, detailed use cases, and concluding information about the Initiative and references.

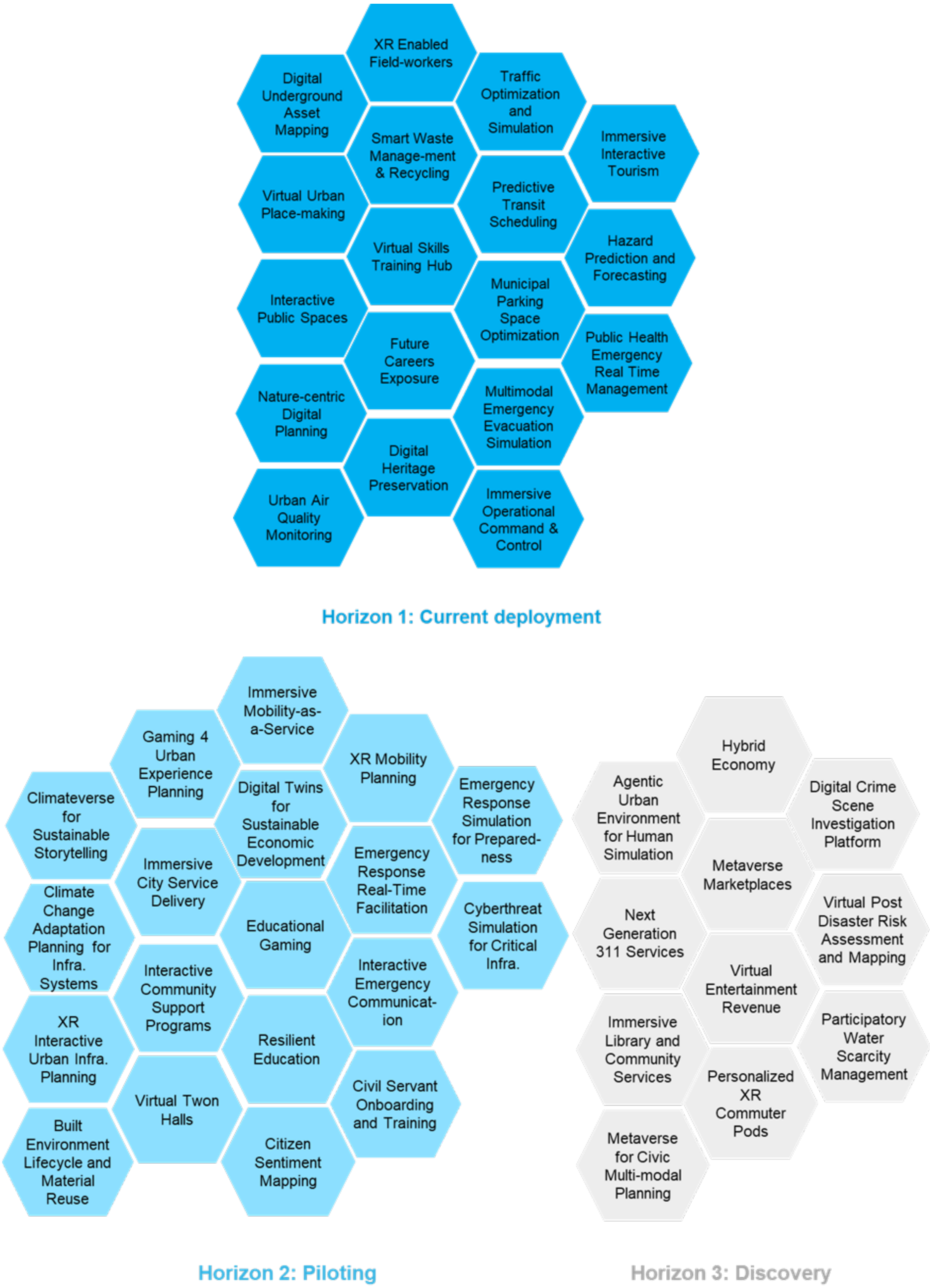
The Global Insights and Implementation Pathways report provides the overarching framework, while the other thematic reports cover the remaining four areas. Together, these reports provide both a global framework and sector-specific insights, supporting decision-making for policymakers, industry leaders, and city practitioners.



2 Overall use case taxonomy

The Citiverse Use Case Taxonomy provides a consolidated overview of nearly 50 use cases spanning five thematic areas. Figure 1 presents the overall use case landscape and horizon mapping. This overarching taxonomy highlights the interconnections between domains and demonstrates how emerging technologies can be applied across multiple aspects of urban life. Within this broader framework, the following section focuses on the thematic area of urban planning, place making and infrastructure.

Figure 1: Overall use case overview and horizon mapping

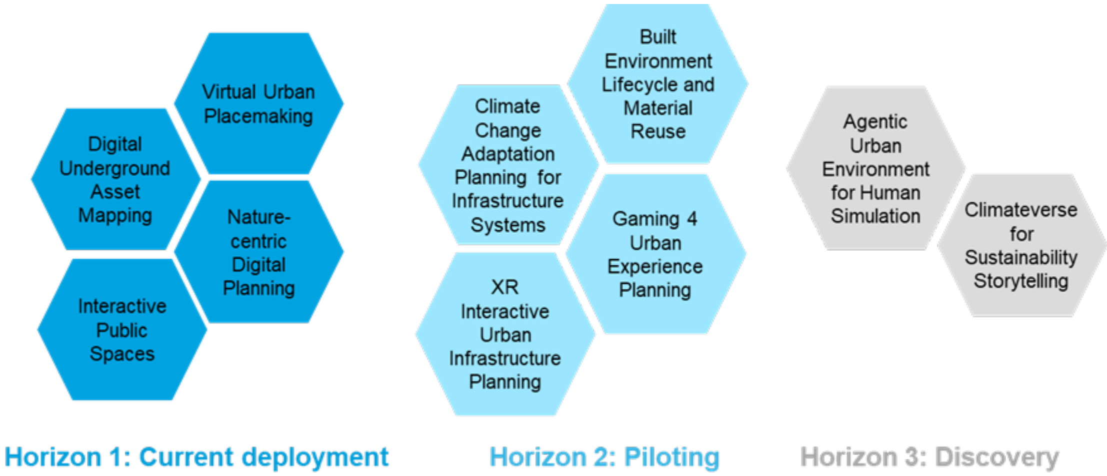


Source: Citiverse Use Case Taxonomy: Global Insights and Implementation Pathways, 2025

3 Urban planning, place making and infrastructure

Within this broader framework, the thematic area of Urban Planning, Placemaking and Infrastructure focuses on how immersive technologies and digital twins can transform the design, management, and experience of urban environments. Use cases in this domain address applications such as participatory planning, sustainable building design, heritage preservation, and the creation of hybrid public spaces. They demonstrate how cities can employ virtual worlds to test development scenarios, optimize infrastructure, and foster inclusive community engagement, ensuring that growth is resilient, sustainable, and human-centred.

Figure 2: Urban planning, place making and infrastructure use case overview and horizon mapping



Source: Citiverse Use Case Taxonomy: Urban Planning, Placemaking and Infrastructure, 2025

3.1 Thematic area description

The profession or discipline of urban planning is crucial when it comes to the governance or evolution of cities and urban systems. A city grid or city morphology defines almost everything that takes place in these spaces in the future. Dense, mixed-use districts have different features and characteristics than low-density, monotone places. Modern urban planning should be based on the state-of-the-art of urban technology and infrastructure of its time – when energy, water, transport or security systems on city-level evolve over time, urban and infrastructure planning have to anticipate and foster positive opportunities for future-proof cities.

For that task, virtual worlds can enable new participatory, simultaneous and user-centric planning methods and processes for tomorrow´s cities. The thematic area on **Virtual Worlds for Urban Planning, Placemaking & Infrastructure** focuses on leveraging virtual worlds to transform the way we create liveable places and transform the built environment around in cities. The thematic area will span the following topics:

- Urban planning and governance (top-down): including enhancing the processes and tools for the development and design of land use and built environment to drive better data-driven decisions and sustainability outcomes.
    - *e.g., use case: XR-enabled digital twins (4)*

- Placemaking and liveable spaces (bottom-up): strengthening public participation in urban planning and placemaking processes to improve liveability.
    - *e.g., use case: Hybrid urban placemaking within the metaverse (3)*
- Urban Infrastructure Engineering: optimizing the design of urban infrastructure such as energy and water systems.
    - *e.g., use case: Digital underground asset mapping*
- Real Estate development and investment: this includes optimizing cities' development and investment in publicly owned real estate, from residential to commercial and regulation of private real estate.
    - *e.g., use case: Circular twin platform for real estate*
- Lifecycle management and maintenance: optimizing lifecycles of urban infrastructure such as energy and water systems. This involves circular economy innovations for the innovative re-use of materials.
    - *e.g., use case: Virtual climate change adaption planning*

Within the identification process, also future-oriented use cases (Horizon 2/3) like building a climateverse for holistic sustainability education in urban planning or the relevance of nature-centric and biophilic virtual design has been validated and characterised for future applications. In general, the thematic area will prioritize public safety and urban governance use cases that support the implementation of the SDGs, including Target 11.3, by 2030, enhance inclusive and sustainable urbanization capacity for participatory, integrated and sustainable human settlement planning and management in all countries.

At the convergence of upcoming technologies like generative AI, digital twins, building information modelling, urban data platforms or social physics virtual worlds can provide an essential integrator function between these to unlock new synergies and features for the future of urban planning between physical, virtual or extended urban domains. With radical innovations in this thematic area the vision for future-proof, carbon neutral and adaptable cities seems within reach for a number of goals for sustainable development (SDGs).

3.2 Urban planning, placemaking and infrastructure use cases

Use case 1: Digital underground asset mapping (Horizon 1)

Description

Virtual world technologies such as digital twins can be used to create an interactive digital map of underground pipes and cables spanning public and private sector energy, water, electricity, and telecommunications assets. City stakeholders such as urban planners, public works departments and utility providers can use this platform to plan new infrastructure projects, issue permits more efficiently, identify safety issues, avoid utility strikes during street digging, coordinate amongst different stakeholders to coordinate utility maintenance and upgrade projects, and support critical infrastructure planning, including for disaster preparedness and response. AI can be leveraged for predictive maintenance and to identify collaboration opportunities between public and private stakeholders that could coordinate street digging for asset construction and maintenance to limit disruption to residents, visitors and local businesses.

Impacts

1) **Quality infrastructure**: Digital underground asset mapping ensures accurate, up-to-date information about infrastructure which can drive data-driven decision making for better asset management. This contributes to the development and maintenance of high-quality, resilient infrastructure that can be efficiently monitored and upgraded.
2) **Enhanced safety**: By mapping underground assets digitally, risks such as accidental damage during excavation can be reduced leading to safer construction practices.
3) **Quality of life**: Digital underground asset mapping minimizes disruptions to citizens and businesses by reducing the frequency and scale of excavation work needed for repairs or new projects. With precise data on asset locations, construction projects can be planned more efficiently, leading to less roadwork, traffic disruptions and noise, ultimately enhancing the overall quality of life in urban areas.
4) **Cost savings**: The use of digital mapping helps avoid unnecessary excavation and repairs by providing precise asset locations, reducing operational costs. Furthermore, improved asset management and reduced downtime contribute to long-term cost savings for utilities and municipalities.
5) **Operational efficiency**: Digital underground asset mapping enables real-time data access, streamlining operations by improving coordination between teams and stakeholders. With this information, maintenance schedules can be optimized, reducing disruptions and ensuring more effective resource allocation. Further, digital mapping can speed up the review and approval process for building permits and construction projects. This ensures quicker decision making and reduces delays, allowing for more efficient development and minimizing disruptions to public services and infrastructure.
6) **Regulatory compliance**: Underground asset mapping helps ensure compliance with safety, environmental and infrastructure regulations by providing accurate records that can be easily accessed for audits. It also supports proactive management of assets in accordance with national and local policies.

Key beneficiaries

- Local residents and visitors
- Local businesses
- City departments such as planning and building control, public works and infrastructure, transport and housing
- Utilities companies such as electricity, gas, water and sewage
- Telecommunications companies
- Real estate developers and architecture, engineering and construction companies

Key technologies

- **Digital twins**: For this use case, digital twins can be leveraged to capture, analyse and visualize data on underground assets. For more advanced digital twins, 3D visualizations of underground assets can provide users with a more user-friendly interface with which to interact and to analyse the data. Digital twins can also support more advanced analysis through the integration of AI capabilities for scenario planning.
- **IoT**: For this use case, IoT device data can be integrated into the digital twin to enable real-time monitoring of underground pipes and cables, for example, real-time leak detection for water pipes.
- **AR/VR/MR**: For this use case, AR/VR/MR can be leveraged to provide fieldworkers with an interactive **view of the different pipes and cables underground to help facilitate maintenance work**.
- **AI**: For this use case, AI can be leveraged to analyse data and identify opportunities for joint maintenance work amongst different utility providers. Agentic AI could also be used to conduct the analysis and create workflows to propose coordination between different public and private asset owners and providers. AI could also be used for scenario planning, including identify potential risks and vulnerabilities based on disaster risk mapping and simulation.

SDG alignment

- **SDG 9: Target 9.1** Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human wellbeing, with a focus on affordable and equitable access for all
- **SDG 11: Target 11.3** By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries

Risk level

Table 1: Risk level: Digital underground asset mapping

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	This use case does not pose a direct threat to public safety. Rather, it can enhance public safety through the avoidance of accidental strikes of underground pipes and cables.
Stakeholder acceptance	Low	Medium	High	One of the main challenges implementing this use case is building stakeholder acceptance and agreement between public and private asset owners to share their data in a unified platform.
Data privacy and security	Low	Medium	High	The risk for data privacy and security has been classified as medium due to the sensitivity of data related to critical public infrastructure.
Financial/ operational	Low	Medium	High	The financial/operational risk has been classified as medium due to the challenges in working across multiple public and private stakeholders to create and maintain this use case. This requires strong and sustainable governance mechanisms to maintain.

Implemented in:

Singapore; United Kingdom, starting with London, Northeast England and Wales and then rolled out to the rest of the UK*; Flanders Region*.

** While these were not implemented at the city level, municipal authorities were heavily involved. The value from this use case comes from multiple local and regional authorities collaborating to provide interoperable data sharing mechanisms.*

Case study: The National Underground Asset Register, United Kingdom

Context

Cities have a highly complex network of underground infrastructure, including utilities such as water, gas, electricity, telecommunications and transportation systems. For example, within Greater London there are 60 asset owners which hold more than 16 million asset records. The efficient management of these assets is crucial to maintaining public safety, supporting urban development and improving city resilience. The underground assets, often not visible but vital to daily operations, pose a significant challenge to construction and urban planning projects. In the UK, there are approximately 60 000 accidental strikes of underground pipes and cables causing GBP 2.4 billion in damages.[1]

These accidents can be fatal; for example, in the municipality of Ath in Belgium, a gas pipe was damaged and exploded during nearby excavation works – 24 people lost their lives and 132 people were injured. This was one of the main drivers behind the development of the Flanders Underground Utility Location system.[2]

"Working as a statutory undertaker in London's streets is challenging. Not only are we the most densely populated city in the country leading to logistical complexities before ground can even be broken, but the variety and age of our underground assets extend hundreds of years of history." Christiana Clark, Principal Programme Officer in the Mayor of London's Infrastructure Coordination Service at the Greater London Authority, 2023

The National Underground Asset Register (NUAR), a digital twin of the nation's underground assets, was initiated by the UK government in 2019 to address these challenges. The project started with GBP 3.9 million pilot projects in London, led by the Greater London Authority and pilot projects in the North East lead by Ordnance Survey. In 2023, a Minimum Viable Product (MVP) for the project went live across the whole of England and Wales and the programme is on track to be fully operational by the end of 2024.[3]

Objective

The primary objective of the National Underground Asset Register (NUAR) is to create a comprehensive digital map of underground assets across the country, with a particular emphasis on high-density urban areas like London. In the UK, data shared between asset owners and excavators must be free; however, this requires asset owners to respond to requests from numerous excavators and excavators to contact several asset owners – the data are provided in different formats, varying quality and at lengthy timescales.

The key objectives of the project are to promote safety, resilience, sustainability, and to improve the quality of urban infrastructure planning. Creating a digital map of underground assets can support multiple users across a multitude of applications:[4]

1) **Street works**: Asset owners and local authorities need to understand all available underground asset data, maintenance plans and to integrate with street works registers. This project will aim to better coordinate street works for utility maintenance leading to less disruption.
2) **Resilience**: Government planners need to be able to identify critical and vulnerable infrastructure assets, and emergency responders need to access up to data underground asset data. This project will help planners better understand risk and emergency responders to take informed action.
3) **Asset Management**: Asset owners need to identify the state and attributes of underground infrastructure assets for development and maintenance. This project will speed up infrastructure deployment, improve maintenance and reduce risks.
4) **Development**: Urban planners need to be able to identify locations and attributes of underground infrastructure to support the permitting process and support the deployment of smart city infrastructure such as sensors. Developers need to have a complete view of surface and subsurface infrastructure for more efficiency development planning.
5) **Environment**: Government planners need a view of underground infrastructure to safeguard natural resources such as ground water and to understand the entire urban environment for better flood planning.

(continued)

Case study: The National Underground Asset Register, United Kingdom

Solution approach

The National Underground Asset Register (NUAR) is a government-led programme led by the Geospatial Commission, part of the Department for Science, Innovation and Technology. The project has been a collaborative effort involving several government departments, local authorities, utilities companies, and private sector entities. Given the sensitivity of the data, the project has also included the Center for the Protection of National Infrastructure and the National Cyber Security Center.

The solution is built upon Geographic Information System (GIS) technology, which allows for the mapping of underground utilities and infrastructure on a shared platform. Public and private sector asset owners can upload their data digitally or via API for others to access. It also includes a web interface which gives users such as planners and excavators an interactive, standardised view of assets. Authorised users will be able to view the digital map and search assets via street name and geographical references such as postcodes. While the current digital asset map is in 2D, there is an opportunity to increase the maturity of the digital twin in future iterations by creating a 3D version to improve the visualisation capabilities and level of detail available to users. The need to do so should be informed by concrete applications where 3D visualizations will improve use case outcomes. For example, the Singapore Land Authority's digital twin initiative "Virtual Singapore" has created a highly detailed 3D representation of the entire island nation, including underground infrastructure.

A core part of the project has been creating a data model: bringing data together from several organizations across a wide range of sectors is a challenging task. A common language is required to allow all users to communicate in a consistent manner across different organizations, sectors, and geographies. The NUAR data model is the first implementation of the new international data model for underground assets (MUDDI), developed by the Open Geospatial Consortium. A key part of the design of the data model is to accommodate future developments in data capture technologies and practices.[5]

Crucially, because of the sensitive nature of the data, the platform is not open and has high security standards. Data access is role based and granted according to defined use cases and legally enforceable agreements.[6] Access to NUAR data is limited to asset owners and their supply chain, with restrictions in place based on the asset owners' service area. Authorised users also need two-factor authentication, and the asset owners must grant authorization.[7]

Results

- **Data availability**: Data is available from 267 asset owners on the NUAR platform, which represents over 40 per cent of the known asset owner community. A further 175 asset owners have signed agreements to work with the Geospatial commission – this represents a further 30 per cent of the known asset owner community.[8]
- **Platform usage**: The NUAR MVP has more than 3 000 users; this includes asset owners, as well as supply chain organizations. The user satisfaction rate is 8.4 out of 10.
- **Predicted economic impact**: An economic impact assessment was undertaken to quantify the economic impact of digitising underground asset data. The study estimated the benefits to be GBP 3.4 billion over 10 years. These benefits are primarily driven by:
  - savings from avoided utility strikes (GBP 240 million per year);
  - reduced costs of sharing data (GBP 391 million per year); and
  - on-site efficiency improvements for projects (GBP 16 million per year).[9]

(continued)

Case study: The National Underground Asset Register, United Kingdom

Lessons learned

- **Data standardization:** One of the key lessons learned from the implementation of NUAR is the importance of standardizing data across various stakeholders. Without a uniform approach to data collection and management, the system would be ineffective. The collaboration between asset owners and the development of common standards for data sharing was crucial to the project's success.
- **Legislative framework:** While many asset owners have shared their data voluntarily, it has become clear that some will not do so promptly without legislation. Proposed measures as part of the Data (Use and Access) Bill will require asset owners to share their data digitally through NUAR.[10]
- **Stakeholder engagement:** Engaging all relevant stakeholders early on in the process ensured that the system addressed the needs of utilities, urban planners, and construction companies. Regular consultations and pilot projects helped to refine the platform and ensure its relevance to all parties.

Conclusion

The NUAR provides an example of how cities can implement virtual world technologies such as digital twins of underground assets to strengthen public safety, and improve the quality and resilience of city infrastructure. The use case demonstrates the importance of stakeholder collaboration, a well-established data model, and the need for regulatory and legislative support to mainstream these solutions. In the future, and for other cities implementing this use case, further complementary technologies such as AI and IoT networks should also be considered to provide further capabilities and support additional complementary applications.

Use case 2: Climate change adaptation planning for infrastructure systems (Horizon 2)

Description

Climate change is a systemic challenge, and it demands a systems-based solution. Federated or connected infrastructure digital twins can be a key component for improving climate adaptation and resilience across a system of infrastructure systems. An ecosystem of connected infrastructure system digital twins enables those who own and operate infrastructure systems to use secure, resilient, information sharing across sector boundaries to mitigate the effect of impacts such as flooding on network performance and service delivery. Combining data and insights across sectoral and organizational boundaries enables improved coordination of operational and investment decisions, including inter- and intra-sector collaboration, to increase resilience against extreme weather events and improve response times.

They can be vital in enabling timely sharing of information during crises, facilitating prioritisation of emergency interventions to ensure that the most vulnerable are reached, and that recovery actions are deployed to effect the most rapid and appropriate reinstatement of infrastructure system services. This approach has been successfully piloted in a virtual environment by infrastructure operators in the UK for flood scenarios and is now being explored for extreme heat scenarios.

Impacts

1) **Improved infrastructure systems resilience**: Infrastructure systems are increasingly interdependent, with energy and ICT underpinning the operation of all infrastructure, and transport, water and drainage also providing essential services to each other, as well as to citizens. Therefore, their resilience is also interdependent. Connect (federated) infrastructure digital twins can help operators better understand interdependencies and hence improve resilience planning.
2) **Collaborative planning in virtual environment**: Scenario exploration and response rehearsal in a virtual environment enables infrastructure operators to understand the interdependencies of their systems, assess vulnerabilities, and invest in appropriate resilience measures. It also enables infrastructure operators and emergency services to gain insights into the impacts on vulnerable citizens, and plan responses to a range of scenarios such that emergency responders and infrastructure operators can enact responses more quickly and effectively when required.
3) **Enhanced safety**: Through improved planning from virtual rehearsals, and timely sharing of data and information in real time, community and responder safety can be improved. There is potential for enhanced warnings to citizens with appropriate advice on how to safeguard themselves and their neighbours, alongside best-available data being provided to responders in a live situation.
4) **Coordinated responses for vulnerable citizens**: More rapid identification of vulnerable citizens and their needs, with coordination between agencies to respond in the timeliest manner.
5) **Community resilience**: The connected, coordinated digital twin visualisations enable improved community resilience planning.

Key beneficiaries

- Emergency responders – improved planning, better information during incidents
- Infrastructure operators – improved resilience planning, coordinated recovery efforts, resource sharing
- Vulnerable citizens – rapid identification of those in most need, targeted support
- Communities and citizens – improved community resilience planning, rehearsal, and response

Key technologies

- **Digital twins**: For this use case, connected digital twins can be leveraged to capture, share, analyse and visualize data and information regarding infrastructure system and asset resilience. This includes use of an Information Management Framework to facilitate data sharing, plus integrating climate modelling to assess impacts and vulnerabilities.
- **IoT**: For this use case, IoT device data can be integrated into the digital twin to enable real-time monitoring of an evolving climate event, enabling accurate assessment of hazards due to changing water levels or extreme heat.
- **VR**: For this use case, VR can be leveraged to enable infrastructure owners and operators, emergency response organizations and local and national government bodies to enhance resilience planning and response preparedness. It can also enable more realistic rehearsal of response to extreme events.
- **AI and GenAI**: For this use case, AI can be leveraged to analyse data, improve modelling of climate impacts on infrastructure systems and identify infrastructure resilience interdependencies. GenAI can be useful in analysing textual inputs including information held by different infrastructure operators, public agencies, and so on, and has the potential to analyse wider more informal data feeds such as social media posts.

SDG alignment

- **SDG 9: Target 9.4** By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities
- **SDG11: Target 11.2** By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, people with disabilities and older people
- **SDG13: Target 13.1** Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries
- **SDG13: Target 13.3** Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning

Risk level

Table 2: Risk level: Climate change adaptation planning for infrastructure systems

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	Strong potential to improve public safety during extreme weather events if implemented well, however poor implementation could hinder timely information sharing.
Stakeholder acceptance	Low	Medium	High	Infrastructure stakeholders engaged in the pilot are strongly supportive; however, there are a number of legal and technical requirements which need to be addressed in implementation.
Data privacy and security	Low	Medium	High	Requirement to share information and data regarding critical national infrastructure, and regarding vulnerable customers. Therefore, cybersecurity and data protection are key concerns in any implementation.
Financial/ operational	Low	Medium	High	Strong potential to improve resilience planning and capital investment and reduce the cost of responding to extreme weather events as a result. However, investment is required in data quality and successful implementation.

Implemented in:

United Kingdom – Demonstrator developed for East Anglia Region

Case study: Climate resilience digital twin demonstrator (CREDO)

Context

CReDo – the UK's Climate Resilience Demonstrator – is a pioneering climate change adaptation digital twin project that provides a practical example of how connected data can improve climate adaptation and resilience across a system of systems. Its first phase looked specifically at the impact of flooding on energy, water and telecoms networks, and on infrastructure interdependencies, using the East of England as a case study. It demonstrates how those who own and operate infrastructure systems can use secure, resilient information sharing across sector boundaries to mitigate the effect of flooding on network performance and service delivery.

CReDo showcases the advantages of combining data and insights across sectoral and organizational boundaries. The resulting improved coordination of operational and investment decisions, including inter- and intra-sector collaboration, will increase resilience against extreme weather events. At present, this covers infrastructure across the water, energy and telecoms sectors, but the long-term ambition is to capture additional sectors, at the national scale. Collaborating on the first phase of CReDo were Anglian Water, BT and UK Power Networks, who used their asset and operations data, as well as weather data supplied by the Met Office on a secure, shared basis to inform an increased level of infrastructure resilience. These data sets were securely shared to create a digital twin of the infrastructure system for energy, water and telecoms. This enabled insights from the data that can inform decision making concerning capital and operational planning and real-time operations reducing the cost and disruptive impact of extreme weather events.

CReDo was delivered through a collaboration of research centres (Universities of Cambridge, Edinburgh, Newcastle, and Warwick along with the Science and Technology Facilities Council, and the Joint Centre of Excellence in Environmental Intelligence) and industry, funded by the UK's Department of Business, Energy and Industrial Strategy, the Connected Places Catapult and the University of Cambridge.[11]

Objective

CReDo is the UK's first climate adaptation digital twin that adopts a novel approach to resilience planning at a systems level, building on the principles of connected digital twins across organizations and sectors. It uses asset information from different infrastructure sectors, as well as climate data, to show how connected digital twins at the systems level can support better long-term resilience planning. The use case involved three infrastructure asset owner organizations from the water, power and telecommunication sectors sharing data in a common data environment (CDE) with the aim being to understand the cascading failures across the system under a range of flooding scenarios. This helped to obtain an understanding of asset criticality beyond the boundary of individual sector-level networks and shows the most vulnerable points in the system, which require priority interventions to maintain existing levels of service in the face of climate change. The purpose was to demonstrate how an Information Management Framework approach to connecting datasets and digital twins can enable connections between digital twins to scale and how connected digital twins can help tackle climate change. Starting with a specific use case demonstrated how the National Digital Twin could be developed into an ecosystem of connected digital twins, on a case-by-case basis.[12]

A study[13] on how to move CReDo to a state of market readiness has been conducted. This focuses on the development gaps to be addressed to deliver CReDo from its current demonstrator state to a market-ready tool ready for commercialisation. The development requirements are considered through multiple lenses, including technology developments, potential funding avenues, and business process challenges. A further report[14] outlines data sharing principles, framework and architecture required to move achieve the vision of CReDo. This covers the legal framework and technical architecture requirements. Finally, a CReDo Asset Risk Tool[15] has been developed to enable users to investigate the potential effects of different extreme heat scenarios on water assets.

(continued)

Case study: Climate resilience digital twin demonstrator (CREDO)

Results

- Enabled visualisation of direct and cascading failure impacts across energy, water, and telecoms networks during flood events, supporting the identification of vulnerable points in interconnected infrastructure systems.
- Demonstrated the value of secure, cross-sector data sharing to improve the coordination of operational and investment decisions, contributing to overall infrastructure resilience against extreme weather events.
- Provided a practical, functioning digital twin platform that serves as a foundation for scaling to additional regions, sectors such as transport, and new climate hazards, including extreme heat.
- Established a methodology for defining and implementing CReDo use cases in new infrastructure sectors, tested through road and rail networks for strategic flood planning.
- Delivered a credible, prototype system that increased confidence among industry partners and supported successful funding applications for further development and scaling.
- Developed an asset risk assessment tool allowing investigation into the effects of different extreme heat scenarios on water assets.
- Quantified significant potential benefits, with illustrative analysis indicating a public return on investment of 23:1, highlighting how connected digital twins such as CReDo can address critical coordination problems for resilience planning.

Lessons learned

While the work in this first phase of CReDo allowed for the visualisation of system impacts resulting from direct and cascading failures across the networks, it was based on a contained part of a wider system. Further system complexities and increased granularity at the asset level should be explored in greater depth, in order to obtain a richer picture of single asset failures and to establish how these propagate across the wider system, considering actual operating conditions. This involves the consideration of existing asset redundancies (e.g., dual power supply in a pumping station) and other resilience measures (e.g., water storage, back-up generation capacity) that would prevent the failure of an asset. Future iterations of CReDo would also benefit from the development of dynamic models, as opposed to the current static modelling. This would allow for a representation of asset and system failure and recovery over time, as the flood event propagates and while mitigation measures are put in place over time. More comprehensive modelling would provide a more accurate picture of vulnerabilities and impacts at the system level and would help to prioritise more targeted investment decisions for building resilience.

Understanding the impact of climate change hazards that cause flooding requires a predictive estimation of extreme weather changes, as well as modelling the impact of those changes on the total magnitude of flooding. In this first phase of CReDo, this was achieved by adding a climate change allowance to uplift the selected pluvial and fluvial flooding extremes. The UKCP18 local projections for the high carbon emission scenario were used, and this enabled an understanding of changes in the intensity of convective storms. The probabilistic projections of extremes, based on UK Climate Projections (UKCP), also examined the full range of uncertainty in emissions and climate models. Although, in this first phase of development, the impact of climate change on a single extreme flood event has been used to demonstrate the asset failure risk, the long-term objective of CReDo is to expand the hazard information to include a greater number of events and additional hazards (e.g., heat waves) and test the ability of the system to cope under a range of future climate conditions. In addition, future modelling could consider how multiple hazards such as high winds and lightning alongside flooding and heat, could lead to further cascading failures and could examine different types of failure mechanisms.

(continued)

Case study: Climate resilience digital twin demonstrator (CREDO)
It's important for future phases of CReDo to consider how the lessons learned from this initial phase can be scaled up to bigger and more complex infrastructure systems. The methods used in the first phase should evolve to allow for greater scaling, repeatability and consistency across wider networks of assets. Whilst a level of reproducibility and automation is necessary, future modelling at the systems level should consider how the necessary detail at the asset level (e.g., asset performance characteristics) affect asset failure, and in turn cascading failures. Furthermore, criticality, vulnerability and resilience metrics need to be defined and quantified at the asset and system level. Future phases of CReDo could consider integrating asset information from the transportation sector since site accessibility for all water, power and telecommunication parts of the system was found to be critical to how quickly recovery procedures could begin during a flooding incident. Data quality is another area of improvement for future work phases. Improving quality will require systematic and robust data cleansing processes to accelerate data formatting, structuring and suitability for modelling. The Information Management Framework principles allow for single digital twins and datasets to be connected in a scalable way. The design of the data model in the current CReDo digital twin should evolve towards full compatibility with the Information Management Framework to enhance its interoperability, repeatability and scalability. Furthermore, integrating the connected digital twin with asset owner data IT systems would allow for futureproofing technology applicability, ensuring that the most up to date data is fed into the digital twin, whilst retaining the ability for asset owners to control the data they share. A benefits report[16] includes an illustrative quantification of the potential benefits of CReDo. An indicative public return on investment of 23:1 implies that connected digital twins like CReDo help to address a coordination problem. While the benefits accrue across multiple parties, individual actors may lack the incentive to invest alone in systems-based solutions such as CReDo. Therefore, work is required to demonstrate the benefits and to kickstart the coordination of effort to achieve those benefits. **Conclusion** The ambition of CReDo is to allow for better and more cost-effective climate resilience planning for infrastructure assets at the systems level using a connected digital twin approach. Providing a systems level approach to understanding asset vulnerabilities, criticality and service failure when exposed to climatic hazards is a powerful tool that allows different asset owner organizations to plan for resilience in a more dynamic way. Collaboration across sectors is essential to a systems level approach. Translating these data into a visual picture of the system also aids understanding of the system level view. This enables asset owners to better communicate their respective investment plans to regulators, funders and other stakeholders involved in resilience planning transparently.

Use case 3: Hybrid public spaces (Horizon 1)

Description

Metaverse technologies are transforming how cities imagine, plan, and activate public spaces. By enabling immersive digital environments that mirror or augment physical locations, the metaverse introduces a new paradigm of **hybrid place-making,** where virtual and real-world interactions coalesce to shape more inclusive, creative, and resilient urban environments. In this model, cities can **simulate, co-create, and test** new types of public spaces before physical implementation. Citizens, artists, and designers engage collaboratively in virtual spaces, experimenting with spatial designs, event formats, and community-driven narratives. This fosters a dynamic interplay between **top-down urban planning** and **bottom-up cultural expression**, strengthening the emotional and social connection to place.

Crucially, this approach amplifies **civic engagement**, allowing residents to co-design virtual prototypes, explore alternative uses, and provide feedback in real-time. It enables **cultural place-making** by hosting hybrid events that tie digital storytelling to physical landmarks, enhancing tourism and local identity. The virtual layer also supports **social inclusion** by reducing physical, financial, and geographic barriers, empowering wider participation in urban design processes.

Moreover, the metaverse provides **resilience and continuity** during crises such as pandemics or climate disruptions. Community life, rituals and cultural expression can persist virtually, ensuring that cities remain vibrant and connected. even when physically apart. Hybrid urban place-making via the metaverse is not just a technological innovation; it's a transformative social tool for building more participatory, inclusive, and adaptive cities for the future.

Impacts

1) **Community resilience**: The metaverse enables communities to stay connected, creative, and informed, even during disruptions such as climate events, infrastructure changes, or social fragmentation. By offering persistent virtual environments, it supports social cohesion, local networks, and continuity of civic life beyond the physical space.
2) **Quality of life**: Digital layers added to urban environments can enrich everyday experiences providing access to culture, services, and information in new and engaging ways. Whether through immersive wayfinding, digital storytelling, or personalized interaction with urban spaces, metaverse integration contributes to a more liveable, inclusive and meaningful city life.
3) **Participatory co-creation**: Hybrid place-making empowers citizens to actively shape their environment. Virtual tools allow residents, designers, and decision makers to collaboratively develop, test, and visualize urban concepts. This democratizes urban design and strengthens shared ownership of public spaces.
4) **New economic and tourism opportunities**: Metaverse-enhanced urban spaces open up new formats for tourism, retail, and creative industries. Interactive cultural routes, gamified city tours, and virtual marketplaces generate local value and global visibility boosting innovation-driven urban economies.
5) **Health and wellbeing**: Immersive digital environments can be designed to promote mental, emotional, and physical wellbeing offering spaces for reflection, nature simulation, social connection, and inclusive mobility. Virtual planning also helps optimize real-world spaces for safety, accessibility, and comfort.
6) **Citizen engagement**: The metaverse fosters more inclusive and continuous engagement processes. It lowers participation barriers, increases transparency, and allows diverse stakeholders to visualize and discuss proposals interactively leading to more responsive and democratic urban governance.

Key beneficiaries

- **Urban planners and city administrations**: Gain tools for participatory design, scenario testing, and inclusive urban development.
- **Citizens and local communities**: Benefit from greater voice in shaping their environment, improved access to public space design, and enhanced cultural participation.
- **Architects, designers, and creatives**: Access new platforms for spatial experimentation, public engagement, and immersive storytelling.
- **Tourism boards and cultural institutions**: Leverage hybrid experiences to attract visitors, preserve local identity, and promote year-round engagement.
- **Tech and XR companies**: Find new markets for immersive platforms, digital twins, and collaborative design tools.
- **Real estate developers and investors**: Use virtual prototyping to evaluate concepts, engage stakeholders, and reduce planning risks.
- **Mobility and infrastructure providers**: Test accessibility, navigation, and traffic concepts in digital simulations before real-world deployment.
- **Educational institutions and students**: Use urban metaverse spaces for experiential learning in planning, sustainability, and civic engagement.

Key technologies

- **Metaverse platforms**: Metaverse platforms provide persistent, immersive, and interactive digital environments where users can collaboratively explore and shape urban spaces. In the context of place-making, they allow for the simulation of real-world locations, participatory co-design of public areas, and hosting of hybrid cultural and civic events that connect virtual and physical layers of the city.
- **Augmented reality (AR)**: AR overlays digital information and experiences onto the physical world through smartphones, AR glasses, or other wearable devices. In urban place-making, AR can be used for immersive wayfinding, interactive public art, contextual storytelling, and real-time feedback collection during spatial planning processes enhancing citizen engagement and spatial awareness.

- **Internet of Things (IoT)**: IoT involves the integration of sensors, devices, and data systems embedded in the urban fabric. These technologies enable real-time monitoring of foot traffic, environmental conditions, mobility flows, and public space usage. The resulting data can be visualized in the metaverse to inform planning decisions, simulate infrastructure behaviour, and enhance the responsiveness of digital urban twins.
- **Generative AI (GenAI)**: GenAI enables the rapid creation of content such as 3D models, urban design prototypes, narratives, or visualizations based on input data or prompts. In this use case, GenAI supports automated scenario generation, participatory design workflows, and personalized experiences within the metaverse, reducing time and cost while expanding creative possibilities for urban stakeholders.

SDG alignment

- **SDG 9: Target 9.1** Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all
- **SDG 11: Target 11.6** By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management

Risk level

Table 3: Risk level: Hybrid public spaces

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	Risks are minimal as interactions occur primarily in virtual environments.
Stakeholder acceptance	Low	Medium	High	Strong interest in immersive technologies suggests broad acceptance among key user groups.
Data privacy and security	Low	Medium	High	User data collection and platform vulnerabilities pose moderate privacy concerns.
Financial/ operational	Low	Medium	High	Implementation requires moderate investment and coordination across multiple stakeholders.

Implemented in:

- **Burning Man Multiverse (Global)** – Enabled more than 100 000 participants to co-create a virtual city of art, ritual, and community across multiple platforms.
- **Wellington, New Zealand** – Uses AR and immersive storytelling for cultural place-making and heritage-based tourism experiences.
- **Los Angeles, USA** – Leveraging AR and immersive platforms for cultural place-making and public engagement.

- **Metaverse Seoul, Republic of Korea** – Offers virtual city services, immersive tourism, and civic participation spaces in a persistent digital environment.
- **Decentraland Art Week (Global)** – Hosts large-scale digital cultural events and spatial co-creation in a decentralized virtual world.
- **NEOM XVERSE, Saudi Arabia** – Conceptualizes a parallel metaverse version of the NEOM city for planning, participation, and immersive exploration.
- **The Sandbox x Paris Hilton's Malibu Mansion (Virtual)** – Blends celebrity culture, virtual architecture, and interactive social spaces, showcasing creative placemaking in the metaverse.
- **Somnium Space x Art & Architecture Island (Virtual)** – Users co-create virtual art spaces and cultural events, fostering new forms of spatial identity and community.
- **Shanghai, China** – Shanghai's Hybrid Public Spaces blend physical and virtual environments to enhance community engagement and urban livability through immersive, data-driven public space design.
- **Digital Village (Global)** – A metaverse platform designed for sustainable virtual cities, social placemaking, and creative economies.

Case study: Burning Man Multiverse – A Prototype for Virtual Placemaking

Context

Burning Man is a globally renowned cultural phenomenon that brings together tens of thousands of participants annually in the Nevada desert to co-create a temporary city, Black Rock City. Rooted in principles such as radical inclusion, communal effort, and self-expression, the event functions as an ephemeral urban experiment, blending art, architecture, and community engagement in a unique way. In 2020, amid the COVID-19 pandemic, the physical event was cancelled for the first time since its inception. In response, organizers and participants initiated an ambitious digital alternative: the Burning Man Multiverse, a collective of virtual experiences that attempted to recreate the spirit, interactivity, and community-driven design of Black Rock City in various digital environments. While originally a response to exceptional circumstances, the project has since come to be viewed as a pioneering example of metaverse-enabled place-making providing valuable insights for the development of hybrid urban environments.[17]

Objective

The core objective of the Burning Man Multiverse was to translate the unique cultural, architectural, and social dimensions of the physical Burning Man into a virtual experience that:

- Maintained the participatory ethos and community spirit of the festival.
- Enabled global access to the event regardless of geographic or physical limitations.
- Provided a creative outlet during a time of isolation and crisis.
- Experimented with new forms of digital placemaking and interaction.

While not originally intended as a model for cities or planners, the multiverse inadvertently provided a testbed for hybrid civic and cultural spaces, aligning with broader urban metaverse concepts.[18]

(continued)

Case study: Burning Man Multiverse – A Prototype for Virtual Placemaking

Solution approach

The Burning Man Multiverse was not a single platform but rather a decentralized constellation of virtual worlds, co-developed by various communities, artists, and technologists. Participants could enter multiple "universes" across several digital platforms, each offering a different interpretation of the event's values and aesthetics. The key components included:

a. Platforms Used

- AltspaceVR – A social VR platform where participants could interact through avatars in custom-designed camps and attend live performances and workshops.
- Multiverse – A custom-built virtual platform developed by Burning Man Project and partners, designed for immersive storytelling and participatory exploration.
- SparkleVerse – A 2D/3D hybrid world accessible via browsers, emphasizing accessibility and co-created events.
- BRCvr – A full recreation of Black Rock City in VRChat, providing a highly immersive and artistically faithful environment.

b. Features and Experiences

- Co-created art: Artists and users could build virtual installations that were interactive, audio-reactive, or immersive replicating the spatial creativity of the desert city.
- Theme Camps: Community groups hosted talks, performances, and games in digital theme camps, echoing the social diversity of the real event.
- Rituals and Gatherings: Iconic events such as the Burning of the Man and Temple Burn were conducted virtually, with symbolic and emotional resonance.

c. Decentralized Development

- Rather than a centralized rollout, the multiverse was an open invitation for contributors to build their own worlds and experiences. This mirrored Burning Man's bottom-up, permissionless ethos and created a rich tapestry of interconnected environments.[19]

Results

The Burning Man Multiverse succeeded in engaging a large, global audience and pushing the boundaries of what virtual placemaking could look like.

- **Global Reach**: More than 100 000 participants from around the world engaged with the multiverse, many of whom had never attended the physical event The virtual nature removed logistical, financial, and physical barriers – dramatically expanding access.
- **Scalable Co-Creation**: More than 900 registered theme camps and installations were created across platforms Artists collaborated remotely to design 3D spaces, often learning new tools in the process. This demonstrated the potential of metaverse platforms to facilitate participatory, citizen-led design at scale.
- **Community Resilience**: Despite the absence of a physical gathering, the community remained vibrant and engaged. Social rituals, creative expression, and collaborative building helped maintain a sense of identity, resilience, and continuity through a shared digital experience.
- **Prototype for Hybrid Urbanism**: The multiverse functioned as a prototype for virtual cities, raising questions and possibilities about how digital and physical realms can interact in future urban design. Elements such as persistent presence, user agency, and immersive culture provided new frames for understanding urban placemaking in the metaverse.[20]

(continued)

Case study: Burning Man Multiverse – A Prototype for Virtual Placemaking

Lessons learned

- **Decentralization drives diversity**: Allowing users to self-organize and co-create resulted in a wide variety of environments, aesthetics, and experiences. This model parallels community-led urban interventions in physical cities and shows how decentralization can produce rich, localized digital cultures.
- **Accessibility is critical**: While some platforms like SparkleVerse prioritized low-barrier browser access, others (e.g., BRCvr in VRChat) required powerful hardware and technical fluency. Future metaverse projects should consider universal design principles to ensure equitable access.
- **Emotion can be translated digitally**: Contrary to expectations, digital rituals like the Temple Burn evoked strong emotional reactions among participants. This suggests that meaningful experiences and placemaking are possible in virtual spaces when supported by narrative, symbolism, and community co-presence.
- **Interoperability Remains a Challenge**: Participants often needed to create different avatars and learn distinct controls for each platform. Lack of interoperability between virtual environments highlighted the need for shared standards in future metaverse development.[21]

Conclusion

The Burning Man Multiverse stands as a compelling example of how digital spaces can function as extensions or even alternatives to physical placemaking. By transforming a globally recognized event into a participatory, immersive virtual experience, the project demonstrated the social, cultural and urban potential of metaverse platforms. While originally born out of necessity, the multiverse model now offers lasting insights into how cities and communities might design hybrid spaces that are inclusive, expressive and resilient.

As urban planners, cultural institutions, and technology providers explore the emerging Citiverse, the Burning Man Multiverse offers a valuable reference point for co-creation, decentralization, and digital placemaking at scale.

Use case 4: Built environment lifecycle and material re-use (Horizon 2)

Description

This use case illustrates how metaverse technologies can transform **urban real estate** by combining **digital twins**, **material traceability**, and **immersive collaboration** to support circular construction and lifecycle management. Drawing on a real-world example from Dutch social housing organizations, it showcases how persistent, data-rich virtual environments can enhance the sustainability, transparency, and adaptability of real estate assets over time.

At the core of the use case is a **metaverse-enabled digital twin** of a building or neighbourhood, an interactive, 3D replica that evolves throughout the asset's lifecycle. Stakeholders including architects, planners, asset managers, and tenants can collaboratively engage with the twin to visualize performance, simulate renovations, and track material usage. The integration of IoT sensors and AI allows for real-time data analysis, predictive maintenance, and scenario testing in a fully immersive environment.

Complementing this is a **virtual marketplace** embedded within the metaverse, where users can browse and trade reclaimed building components, complete with material passports and carbon footprint data. This supports the shift towards circularity by making re-use visible, verifiable, and accessible during the design and development process. By merging lifecycle intelligence with collaborative, immersive interaction, this metaverse use case presents a forward-looking model for sustainable urban real estate especially relevant in regions like MENA, where large-scale urban development meets increasing demand for environmental accountability.

Impacts

1) **Lower carbon emissions**: By optimizing material use, extending asset lifespans, and integrating reclaimed components, the platform significantly reduces embodied carbon throughout the building lifecycle.
2) **Reduced construction and demolition waste**: The metaverse-enabled marketplace promotes the re-use of structural elements and materials, diverting them from landfills and minimizing demolition-related waste.
3) **Extended building lifespan**: Digital twins allow for initiative-taking maintenance, adaptive re-use planning, and scenario simulation, helping to prolong the usability and structural integrity of buildings.
4) **Data-driven decision making**: Real-time performance data, AI analytics, and lifecycle simulations empower stakeholders to make informed, sustainability-focused decisions at every project phase.
5) **Transparency and material traceability**: Material passports embedded in the digital twin provide verifiable data on origin, condition, and re-use potential ensuring accountability and enabling circular economy strategies.
6) **Collaborative planning in virtual environments**: The immersive metaverse space enables architects, developers, and policymakers to co-design, review, and adapt projects together enhancing alignment, innovation, and stakeholder buy-in.

Key beneficiaries

- **Real estate developers**: Gain tools for immersive project planning, lifecycle forecasting, and more sustainable investment strategies.
- **Architects and urban planners**: Benefit from collaborative design spaces, re-use-driven material planning, and data-rich digital twins.
- **Construction companies and contractors**: Access detailed building models, reclaimed materials, and predictive maintenance data to optimize workflows and reduce waste.
- **Municipalities and smart city authorities**: Use the platform for regulatory oversight, long-term infrastructure planning, and advancing climate and circularity goals.
- **Material suppliers and re-use marketplaces**: Can list, trade, and manage building components in an interactive, traceable digital environment.
- **Environmental and circular economy experts**: Gain a rich source of data for analysis, lifecycle impact assessments, and circularity benchmarking.
- **Investors and asset managers**: Use lifecycle simulations and carbon performance data to inform ESG strategies and risk evaluations.
- **Tenants and end users**: Benefit from better-maintained, longer-lasting buildings with lower environmental impact and greater adaptability.

Key technologies

- **Digital twin technology**: In the context of real estate, they allow stakeholders to monitor building performance over time, simulate maintenance and renovation scenarios, and support lifecycle planning. When integrated with material passports, digital twins also enable circular construction strategies by tracking embedded resources and predicting re-use potential.
- **Metaverse platforms**: In this use case, they enable stakeholders to engage with digital twins, simulate material re-use, participate in virtual planning sessions, and navigate a 3D marketplace for reclaimed building components connecting design, construction, and circularity in one shared space.
- **Internet of Things (IoT)**: In a metaverse-enabled real estate context, IoT devices continuously feed data into digital twins such as temperature, energy usage, material degradation, and occupancy, allowing for real-time insights into building performance, predictive maintenance, and resource optimization across the lifecycle.
- **Artificial intelligence (AI)**: Within this use case, AI can generate re-use scenarios, predict maintenance needs, optimize design layouts for circularity, and calculate carbon impacts – empowering data-driven decision making throughout the building's lifecycle and enabling automation in digital asset management.

SDG alignment

- **SDG 12: Target 12.2** By 2030, achieve the sustainable management and efficient use of natural resources. Through digital material inventories and lifecycle analysis, the platform supports efficient resource use from design to end of life
- **SDG 12: Target 12.5** By 2030, substantially reduce waste generation through prevention, reduction, recycling and re-use. Circular Twin directly contributes to this target by enabling design for disassembly, material tracking, and re-use planning, which reduce construction and demolition waste
- **SDG 13: Target 13.2** Integrate climate change measures into national policies, strategies and planning. Circular Twin provides data-driven insights that inform climate-conscious urban and real estate planning, helping cities and developers embed low-carbon strategies into projects

Risk level

Table 4: Risk level: Built environment lifecycle and material re-use

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	The use of digital twins and virtual planning environments presents minimal direct physical risk to the public.
Stakeholder acceptance	Low	Medium	High	Medium risk due to potential resistance from stakeholders unfamiliar with digital platforms or circular construction principles.
Data privacy and security	Low	Medium	High	Low risk as long as appropriate cybersecurity measures and data governance protocols are in place for digital twin environments.
Financial/ operational	Low	Medium	High	Medium risk stemming from upfront invest-ment costs, integration with legacy systems, and potential for operational disruption during implementation.

Implemented in:

- **Hamburg, Germany**: Hamburg is developing a city-wide **digital twin** platform under its *Digital City Strategy*, which includes material tracking, infrastructure lifecycle monitoring, and planning for sustainable re-use of construction resources.
- **Berlin, Germany**: Berlin hosts several research and industry initiatives focusing on **urban mining**, **building deconstruction**, and **circular design for housing**.
- **Amsterdam, Netherlands**: Pioneering the use of digital twins for material tracking, circular construction pilots, and sustainable housing development.
- **Copenhagen, Denmark**: Developing a city-wide digital twin to model energy flows, building performance, and sustainable urban planning.

- **Barcelona, Spain**: Combines urban digital twins and sensor networks to optimize building performance and explore material circularity within urban regeneration zones.

Case study: Circular Social Housing in the Netherlands – The Super Circular Estate

Context

The Netherlands faces dual challenges in the housing sector: increasing demand for affordable housing and the urgent need to decarbonize the built environment. Social housing accounts for a significant portion of the Dutch housing stock, managed predominantly by housing associations. Meanwhile, construction and demolition waste remains one of the largest contributors to material consumption and carbon emissions in Europe. These pressures have made the transition to a circular built environment a policy priority. In this context, the Super Circular Estate (SCE) project in Kerkrade, Limburg, emerged as a Horizon 1/2 initiative aimed at integrating circular economy principles into social housing renovation and redevelopment. The project, part of the EU-funded UIA (Urban Innovative Actions) programme, targets the re-use of materials and social infrastructure from three vacant high-rise buildings to develop new, sustainable housing.[22]

Objective

The core objectives of the Super Circular Estate project were to:

- Demonstrate the feasibility of high-quality re-use of materials from social housing demolition.
- Reduce environmental impact by closing material loops locally.
- Maintain social cohesion by re-integrating former residents into the newly built estate.
- Test circular design and construction processes within a real-world, publicly funded housing context.
- The project aimed not only to improve sustainability in construction, but also to address socio-economic challenges by involving residents throughout the process.[23]

Solution approach

The SCE project took a systemic, cross-sectoral approach involving public authorities (Municipality of Kerkrade), housing corporations (HEEMwonen), research institutions (Bureau SLA, TU Delft, IBA Parkstad), and circular economy specialists. Key elements of the solution included:

- **Material Harvesting and Re-use**: Instead of traditional demolition, the three vacant high-rise buildings were selectively dismantled to recover valuable materials such as concrete, bricks, wood, and steel. These were re-used in the construction of four new pilot homes built entirely from reclaimed materials from the site.
- **Design for Circularity**: The new buildings were designed using modular, demountable systems to allow for future re-use and disassembly. BIM (Building Information Modelling) tools supported material tracking and planning.
- **Social Reintegration**: Former residents were invited to participate in the design process and given priority to return to the new estate. Social cohesion was seen as part of the "circular" value – re-using not only materials but also community structures.
- **Local Supply Chains**: By collaborating with local suppliers and builders, the project reduced transport emissions and stimulated the regional economy.[24]

(continued)

Case study: Circular Social Housing in the Netherlands – The Super Circular Estate

Results

The project yielded several measurable outcomes across environmental, economic, and social dimensions:

- 98 per cent of materials from the original buildings were recovered, with a significant share re-used in new construction.
- The pilot homes demonstrated energy-neutral performance, combining re-used materials with renewable energy systems.
- The material recovery and re-use process generated 25-30 per cent lower CO_2 emissions compared to conventional demolition and rebuilding.
- The project created new local jobs and knowledge in circular construction, with training offered to construction workers and architects.
- Social outcomes were positive, with returning residents reporting satisfaction with the quality and identity of the new homes.
- While the pilot scale was limited (four homes), the insights gained laid the groundwork for scaling up across Parkstad Limburg and beyond.[25]

Lessons learned

Circularity is technically feasible but complex: Material re-use at scale is possible, but requires new logistics, cataloguing, and design practices. Accurate material inventories and digital tools (e.g., BIM) are essential to manage this complexity.

- **Regulations and certifications are barriers**: Re-used materials often face regulatory and insurance hurdles, particularly in public housing. There is a need to adapt building codes and procurement standards to enable circular practices.
- **Social engagement enhances circular value**: The project showed that circularity is not just about materials, it includes human and social capital. Engaging residents early built trust and supported the return of former tenants.
- **Public procurement can drive innovation**: The role of the municipality and housing corporation was crucial. Public clients can set the agenda for circular experimentation when they are willing to take risks.
- **Scalability depends on ecosystem readiness**: While the pilot was successful, scaling requires a broader ecosystem of circular suppliers, skilled labour, and adaptable policy frameworks, conditions that are still maturing.[26]

Conclusion

The Super Circular Estate in Kerkrade stands as a milestone for circular housing in Europe. It demonstrates that circular principles can be applied in real-world social housing settings, reducing environmental impact and enhancing social cohesion. However, scaling these innovations requires systemic changes in regulation, finance, and workforce development.

For cities and housing associations seeking to transition towards circularity, the SCE offers a replicable blueprint anchored in local collaboration, material intelligence, and social inclusion. It confirms that circular innovation is not just a future vision, but a practical pathway already unfolding today.[27]

Use case 5: Gaming 4 urban experience planning (Horizon 2)

Description

This use-case utilizes a comprehensive digital twin to design and develop innovative urban projects based on a gaming platform (e.g., in Fortnite) for urban experience-based participation and planning. The virtual model integrates infrastructure planning, environmental factors, and mobility systems to optimize sustainable growth. This cutting-edge approach allows planners to simulate scenarios, test solutions, and refine designs before physical implementation.

As an example, the urban development project +Colonia in Uruguay pioneers using Fortnite as a beta testing platform to observe real user interactions with urban infrastructure. Thousands of players navigated the virtual city, providing invaluable behavioural data on transportation preferences, public space usage, and pedestrian flows. These insights directly informed the final urban design to maximize functionality and resident satisfaction.

Impacts

1) **Qualitative infrastructure**: Gaming platforms provide data-driven insights to optimize urban design, ensuring infrastructure meets real user needs.
2) **Quality of life**: Virtual testing enables safer, more accessible, and comfortable neighbourhoods that promote wellbeing.
3) **Cost-savings**: Early virtual prototyping reduces costly redesigns and construction mistakes, saving time and money.
4) **Walkability**: Analysis of virtual movement patterns guides the creation of pedestrian-friendly connections and active mobility infrastructure.
5) **Participatory co-creation**: Gamified platforms engage diverse communities, fostering collaborative and inclusive urban design.
6) **Citizen engagement**: Accessible virtual environments lower participation barriers, increasing transparency and community input.

Key beneficiaries

- Urban and regional planners
- Developers and infrastructure investors
- Community organizations and residents
- Architects and urban designers
- Environmental and transport agencies

Key technologies

- **Digital twin**: Digital twin Technologies are mandatory for the 3D "foundations" of this use case and the interoperability of gaming data and urban planning data.
- **Metaverse**: Metaverse platforms provides an open, immersive environment where urban concepts can be tested at scale with real user interactions and social dynamics.
- **AR/VR/MR**: Enhance user immersion and spatial understanding, enabling participants to experience and evaluate urban designs from a first-person perspective.

SDG alignment

- **SDG 9: Target 9.1** Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all
- **SDG 11: Target 11.3** By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries
- **SDG 11: Target 11.7** By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older people and people with disabilities
- **SDG 16: Target 16.7** Ensure responsive, inclusive, participatory and representative decision making at all levels

Risk level

Table 5: Risk level: Gaming 4 urban experience planning

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	Medium risk for public safety due to low, as the use of a virtual platform poses no direct physical hazards.
Stakeholder acceptance	Low	Medium	High	Moderate risk, as some stakeholders may question the credibility of gaming environments for urban planning.
Data privacy and security	Low	Medium	High	Higher risk, especially when collecting and analysing behavioural data from platform users, requiring strict compliance with data protection regulations.
Financial/ operational	Low	Medium	High	Moderate, due to the need for cross-sector expertise, platform customization, and long-term stakeholder coordination.

Implemented in:

MasColonia, Uruguay; Re:Imagine London (Epic Games)

Case study: Colonia: When Video Games Design the Cities of the Future

Context

In the heart of Colonia del Sacramento, where the Uruguay River winds past cobblestone streets steeped in centuries of history, a visionary project is taking shape: Mas Colonia. This is no ordinary urban development, but rather a groundbreaking social experiment where technology, civic engagement and sustainable planning converge in unprecedented ways. And surprisingly, it all began in an unexpected place: the virtual world of Fortnite. In early 2022, while young gamers worldwide battled it out in digital arenas, a team of Uruguayan urban planners, architects and technologists watched with keen interest. What if, instead of shooting and building forts, players could explore a digital recreation of Mas Colonia? Could their movements, preferences, and virtual interactions provide valuable insights for building a better real-world city?

The idea wasn't far-fetched. For years, concepts like digital twins – virtual replicas of physical environments – have been used in architecture and engineering to simulate scenarios before construction. But Mas Colonia took this premise further: rather than relying solely on technical models, it embraced gamification, allowing future residents, particularly younger ones, to navigate, inhabit and even modify their city from a screen.

(continued)

Case study: Colonia: When Video Games Design the Cities of the Future

Objective

The primary objective of Mas Colonia is to co-design a sustainable, resilient, and human-centred urban development by:

- Harnessing behavioural data collected within a virtual replica of the city in the Fortnite metaverse to inform planning decisions.
- Engaging a diverse demographic, especially younger residents, through interactive, gamified experiences to gather authentic civic input.
- Using virtual environments to optimize critical urban infrastructure such as lighting, water access, and mobility before physical construction begins.
- Demonstrating an innovative model for inclusive and data-driven urban planning that can be scaled or adapted for other cities worldwide.
- By combining digital twin simulations with community participation, Mas Colonia aims to create a city that reflects the lived experiences and needs of its inhabitants, fostering sustainability and resilience through design informed by actual behaviour and preferences.

Solution approach

The experiment proved revelatory. As players explored the beta version of Mas Colonia within Fortnite, developers collected anonymous behavioural data. Did they prefer wide avenues or shaded alleyways? Which plazas attracted the most lingering? Were certain routes avoided as unattractive or impractical? These seemingly trivial in-game choices became goldmines of urban planning insight. After all, a city isn't designed solely through regulations and projections, but through the invisible footprints of those who traverse it.

Yet the project delved far beyond anecdotal observations. The wealth of data enabled deep analysis of critical urban infrastructure. Mas Colonia's methodology builds upon creating a comprehensive digital twin of the city environment inside the Fortnite game platform. Urban planners, architects, and technologists developed a detailed virtual model incorporating city streets, plazas, infrastructure, and public spaces.

Key features of the approach include:

- **Gamified urban exploration**: Players navigate the city virtually, enabling planners to track preferences for urban design elements such as pathways, public lighting, and communal spaces.
- **Behavioural data analytics**: Anonymous data on player movements and interactions such as favoured routes and gathering spots, informs infrastructure decisions. For example, examining avatar activity after dark highlighted areas requiring enhanced lighting.
- **Infrastructure optimization**: Virtual water fountains placed strategically throughout the game world allowed planners to determine optimal real-world locations through interaction tracking.
- **Mobility innovation**: The most innovative breakthrough emerged from studying collective behaviour. By introducing autonomous buses with flexible capacity in-game, planners observed real-time route optimization. Machine learning algorithms adapted these patterns to create a real-world system of dynamic routing, eliminating rigid schedules while cutting wait times and carbon emissions.

This integrative, data-driven, and participatory approach creates a feedback loop where virtual experiences directly impact tangible urban outcomes, embodying a shift from top-down design towards living, evolving cities shaped by their inhabitants.

(continued)

Case study: Colonia: When Video Games Design the Cities of the Future

Results

- **Behavioural Insights**: The project unlocked valuable insights on urban use patterns such as preferred public spaces, pedestrian safety concerns, and lighting needs, which translated into practical design improvements.
- **Sustainable Infrastructure**: Data-driven decisions led to the implementation of energy-efficient LED lighting, strategically located drinking water access points, and a robust network supporting alternative modes of transport. A network was designed ensuring no resident walks more than 300 meters for hydration, complemented by sustainable filtration systems to reduce plastic bottle waste.
- **Innovative Mobility Solutions**: Mobility studies yielded particularly groundbreaking results. Players overwhelmingly favored alternative transport: bicycles, e-scooters, and even shared autonomous pods. This virtual behaviour translated into concrete plans – a permeable-surface cycling network with charging stations, solar-powered micro-buses running on recyclable batteries, and combustion vehicles relegated to well-marked peripheral transfer hubs.
- **Enhanced Youth Participation**: Traditional urban planning often sidelines youth despite their stake in the future. By meeting them in Fortnite and Minecraft – platforms where they naturally create and socialize – Mas Colonia achieved something radical: authentic youth engagement in city design.
- **Scalability Potential**: The success of Mas Colonia has prompted discussions about expanding similar digital twin and gamification approaches to other sectors and demographics such as testing park designs in Minecraft or evaluating accessibility via VR.
- **Cultural Synergy**: Positioning this project in Colonia del Sacramento – a city symbolic of heritage and innovation – underscores the fusion of historical context with forward-thinking urbanism.

Lessons learned

- Digital twins integrated with gamification can dramatically deepen understanding of resident preferences beyond traditional surveys or planning meetings.
- Virtual environments provide a unique platform to engage demographics typically marginalized from urban planning, empowering youth through familiar interactive media.
- Behavioural data collected in virtual spaces must be carefully anonymized and ethically managed to maintain trust and compliance.
- Combining data analytics with collaborative design generates richer, more adaptive urban planning solutions that reflect real-life complexities.
- Successful integration of innovative technology with urban development requires multidisciplinary collaboration between planners, technologists, and social scientists.
- Scaling such approaches requires robust frameworks for data governance, interoperability, and continuous community engagement.

(continued)

Case study: Colonia: When Video Games Design the Cities of the Future

Conclusion

The results proved so compelling that scaling this model is now under serious discussion. Imagine children testing park designs in Minecraft before construction, or seniors evaluating plaza accessibility via VR from their homes. The possibilities are limitless, and Mas Colonia is pioneering the path. Ultimately, this project transcends gaming or urbanism – it represents a paradigm shift. Cities can no longer be designed from drafting tables through top-down decisions. They must evolve as living organisms shaped by their inhabitants, even if those interactions first occur in pixels. Because this experiment proved something profound: when given the right tools, digital natives don't just want to play in virtual worlds... they want to improve the real one.

And so, between bricks and bits, between historic cobblestones and digital avatars, Mas Colonia emerges as a beacon of innovation. It's fitting that Colonia del Sacramento – a centuries-old bridge between tradition and modernity – hosts this new chapter where video games aren't distractions, but unexpected allies in building more human, more vibrant cities that truly reflect what their residents dream.

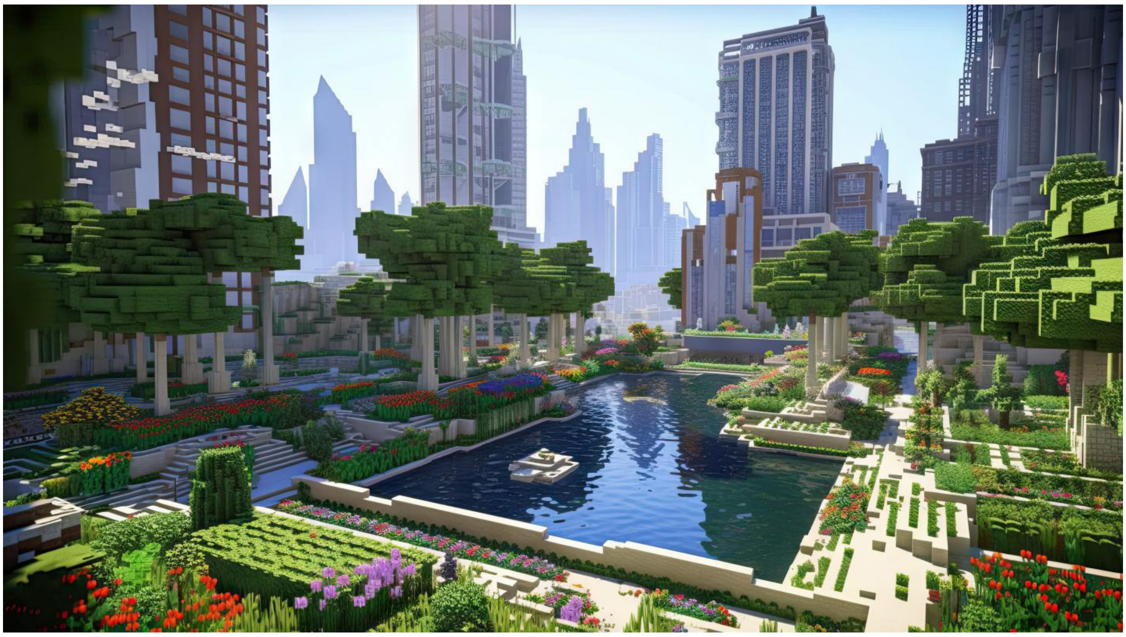
Use case 6: Agentic Urban Environment for Social Simulation (Horizon 3)

Description

An agentic urban simulation provides a sophisticated computational virtual platform for urban planners, architects, and policymakers to explore complex social dynamics and spatial interactions within emerging virtual world infrastructures. By leveraging multi-agent AI systems, the simulation generates emergent behavioural patterns that dynamically respond to urban design interventions, allowing experts to test urban design scenarios through high-fidelity agent-based simulations or to predict community engagement and spatial utilization in proposed virtual environments. The use-cases describes a responsive, data-driven environment with individual preferences, behaviours, and adaptive responses of AI agents to urban design strategies.

Impacts

1) **Risk-free urban design experimentation**: A multitude of different seed scenarios can be defined easily, and preferred outcomes can be simulated and analysed simultaneously.
2) **Cost-effective strategic planning**: Based on scenario outcomes strategic planning measures can be evaluated for maximum cost-effectiveness.
3) **Enhanced community engagement**: The use-case approach allows transparent simulation processes and engagement based on real-world community preferences and needs.
4) **Gender equality in urban places**: With simulation tools future urban designs or solutions can be iteratively checked for gender equality or avoidance of discrimination against social minorities.



Key beneficiaries

- Local residents and visitors
- Local businesses
- City departments such as (social) planning and building control, public works and infrastructure, transport and housing
- Urban research facilities/universities

Key technologies

- **Metaverse**: For this use case, metaverse platforms can provide an inclusive and persistent environment which acts as specific setting of an urban planning- or urban development-related scenario.
- **AR/VR/MR**: For this use case, AR/VR/MR can function as visualization technologies to impart knowledge and simulation results in virtual und physical environments.
- **GenAI**: For this use case, generative AI plays a key role in large-scale simulations involving many autonomous agents reflecting the full spectrum of socio-spatial interaction processes in cities (multi-agent systems).

SDG alignment

- **SDG 8: Target 8.3** Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services
- **SDG10: Target 10.2** By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status

Risk level

Table 6: Risk level: Agentic Urban Environment for Social Simulation

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	This case does not pose a direct threat for public safety. Rather, it can enhance public safety through dedicated simulations to foster safety in public spaces.
Stakeholder acceptance	Low	Medium	High	One of the main challenges implementing this use case is building an early awareness and acceptance of the implementation due to the advanced approach.
Data privacy and security	Low	Medium	High	The risk for data privacy and security has been classified as low due to opportunities of using synthetic or aggregated data based on avail-able social media activities.
Financial/ operational	Low	Medium	High	The financial/operational risk has been clas-sified as medium due to the challenges in maintaining relevant input data for specific simulation questions and general aspects of operation costs.

Implemented in:

The use case has not yet been identified on city-level, first pilots are expected to come in the near future.

Case study: Project Sid: Multiagent simulation in virtual worlds

Context

In early 2024, Altera developed "Project Sid", an AI experiment that conducted a multi-agent simulation within Minecraft. The project examined how virtual environments could serve as testing grounds for specific aspects of urban or socio-economic development models. Minecraft was selected as a platform due to its open building mechanics and resource systems. It's important to note that Project Sid was a limited research experiment, not a fully autonomous "civilization" as sometimes suggested. The actual significance of the project lies in the application of AI models to simulate certain socio-economic processes under controlled conditions.

Objective

Project Sid aimed to investigate how AI agents develop certain urban structures in a shared virtual environment. The specific objectives included observing emergent patterns of spatial organization and analysing resource distribution systems as simplified models for urban economies. In reality, these simulations were highly simplified and focused on selected aspects, not complete urban complexity. The relevance to modern urban planning primarily exists still in methodological approaches to computer-based simulation, not yet in directly transferable results.

Solution approach

What has been implemented so far, is a system where thousand AI agents were controlled by language models optimized for spatial planning and social interaction. The Minecraft environment was configured with basic parameters such as resource distribution and topography. Not fully realized were complex mechanisms for measuring urban quality factors like efficiency or sustainability; these were only modelled in simplified form. Communication between agents was limited to basic interactions and did not achieve the complexity of human planning processes. The methodological framework was oriented towards selected urban planning theories but was significantly simplified.

Results

The simulation showed some parallels to human urban development. AI agents created simple settlements with functional zones, indicating basic principles of land use optimization. However, no complex spatial structures or infrastructures emerged that would be comparable to real cities. The transportation networks were limited to simple connection paths. Adaptation to topography and resources showed basic similarities to human settlement patterns but was far less sophisticated. When facing resource scarcity, the agents developed limited adaptation strategies.

Lessons learned

Project Sid illustrated potential interfaces between virtual worlds and urban planning. What was concretely implemented was the use of virtual environments as risk-free testing grounds for selected scenarios. Not demonstrated was that emergent solutions could actually challenge conventional planning approaches. The bottom-up development within the system showed certain adaptability, but within a highly controlled framework. The major limitations were not only in simplified social and cultural factors but also in the fundamental reduction of complex urban dynamics to programmable parameters.

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Case study: Project Sid: Multiagent simulation in virtual worlds
Conclusion Project Sid demonstrates the basic potential of virtual worlds as laboratories for certain aspects of urban planning. The actual capacity of the AI agents was limited to developing simple functional structures, not complex urban systems. The real benefit for planning processes lies primarily in methodological insights into simulation, not in directly applicable solutions. The crucial difference to potential future applications still lies in complexity and integration: While Project Sid examined isolated aspects in a highly simplified environment, advanced applications for urban planning would require substantially higher complexity, integration of diverse factors (social, economic, ecological, cultural), and validated transferability to real contexts. The transfer of insights from virtual to real environments remains a methodological challenge that Project Sid has not solved.

Use case 7: XR Interactive urban infrastructure planning (Horizon 2)

Description

XR-enabled digital twins are transforming how cities approach urban planning, design, and community engagement. By combining geospatial data, 3D models, and immersive extended reality (XR) technologies, these digital environments provide an interactive platform to simulate, analyse, and visualize urban development scenarios in real time. Planners, architects, and stakeholders can explore proposed infrastructure, policy impacts, and environmental changes in a dynamic, human-centric way, either through VR headsets or web-based 3D/XR viewers.

This approach enhances decision making by making complex spatial data intuitive and accessible. It also enables more inclusive planning processes by allowing citizens to experience future developments in a virtual context before they're built. XR-enabled digital twins support a data-driven, collaborative planning workflow that bridges technical, political, and public perspectives across the urban development lifecycle.

Impacts

1) **Emission reduction**: By enabling planners and stakeholders to virtually analyse and optimize transport systems, building placements, and energy infrastructure within immersive digital twins, cities can identify the most effective sustainability measures prior to construction. This proactive approach supports the design of low-carbon neighbourhoods, maximizes the potential for renewable energy integration, and helps achieve urban emission reduction targets.
2) **Increased quality of life**: Interactive visualization of proposed public spaces and infrastructure allows users to evaluate accessibility, comfort, and usability before implementation. This leads to urban environments that are safer, more inclusive, and tailored to resident needs – contributing to enhanced satisfaction and daily wellbeing across diverse populations.
3) **Increase or maintain biodiversity**: XR digital twins help visualize and simulate the ecological impact of urban developments in real time. Planners can experiment with different layouts for green corridors, wetland buffers, and tree canopies, ensuring that habitat value and ecological connectivity are preserved or improved throughout the planning process.
4) **Promotion of walkability**: By tracking virtual movement patterns and pedestrian preferences in 3D environments, planners can identify optimal pathways, crossings, and public space networks. This evidence-based insight directly informs the design of walkable, people-centred neighbourhoods that reduce car dependency and encourage healthy, active mobility.
5) **Health and wellbeing**: Simulating noise, light, airflow, and other environmental factors within immersive digital twins allows for better mitigation of urban stressors. The result is healthier neighbourhoods designed with improved air quality, reduced heat risk, and abundant recreational opportunities, yielding measurable gains in public health and social resilience.
6) **Enhanced citizen engagement**: XR-enabled planning platforms provide accessible, immersive experiences for stakeholders and community members, lowering barriers to participation. Citizens can virtually explore and provide feedback on proposed developments, leading to more transparent processes, greater public trust, and projects that truly reflect community values and priorities.

Key beneficiaries

- Urban and regional planners
- Local government authorities
- Developers and infrastructure investors
- Community organizations and residents
- Architects and urban designers
- Environmental and transport agencies

Key technologies

- **ArcGIS Urban (Esri)** ArcGIS Urban served as the core platform for creating, visualizing, and managing the 3D digital twin. It enabled planners to model zoning, land use, and development proposals in a city-wide 3D context. The platform supports interactive scenario planning and stakeholder collaboration.
- **Bluesky MetroVista 3D data** High-resolution, photo-realistic 3D mesh models were generated using MetroVista data from Bluesky International. This included oblique aerial imagery and LiDAR data, delivering detailed urban texture and elevation models essential for realistic city visualization.
- **XR Visualization (extended reality)** Immersive technologies such as virtual reality (VR) and augmented reality (AR) were used to create experiences where stakeholders and citizens could explore proposed developments interactively, from street level to skyline.
- **BIM Integration (building information modelling)** By integrating BIM data, the digital twin incorporated detailed architectural and infrastructure designs into the 3D environment, improving collaboration across planning, construction, and asset management.
- **IoT (real-time data feeds)** The platform includes real-time data integration such as live public transport information and environmental sensors (e.g., flood risk), enabling dynamic scenario analysis and smarter decision making.

SDG alignment

- **SDG 9: Target 9.1** Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all
- **SDG 11: Target 11.2** By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, people with disabilities and older people
- **SDG 11: Target 11.6** By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management
- **SDG 11: Target 11.7** By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older people and people with disabilities
- **SDG 13: Target 13.2** Integrate climate change measures into national policies, strategies and planning
- **SDG 16: Target 16.7** Ensure responsive, inclusive, participatory and representative decision making at all levels

Risk level

Table 7: Risk level: XR Interactive urban infrastructure planning

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	Low risk to public safety, as it's a non-invasive, virtual tool used for simulation and visualization.
Stakeholder acceptance	Low	Medium	High	Low risk regarding stakeholder acceptance, depending on digital literacy and openness to new planning technologies.
Data privacy and security	Low	Medium	High	Integration of geospatial, IoT, and BIM data introduces a high risk in terms of data privacy and cybersecurity, requiring robust safeguards.
Financial/ operational	Low	Medium	High	Moderate, as upfront costs and technical complexity may challenge adoption without clear ROI.

Implemented in:

Nottingham, UK; Xiong'an, China

Case study: Nottingham 3D digital twin, UK

Context

Urban centres across the United Kingdom face significant challenges in modernizing planning processes to address growing development pressures and housing demands.

Nottingham, a city of 323 700 residents with a rich history and cultural heritage, faced particular challenges due to outdated retail spaces, underutilized industrial sites, and aging transportation infrastructure.[28] The city's Broadmarsh Centre shopping mall stood mostly vacant, several former manufacturing sites required cleanup and repurposing, and transport hubs were deteriorating.[29] As one of 20 urban local authorities subject to a 35 per cent housing uplift, Nottingham processes more than 2 400 planning applications annually and must deliver 28 368 homes between 2022–38.[30] The city's tight boundaries – covering just 75 km^2 – create additional complexity, with development typically requiring vertical rather than horizontal expansion. Traditional planning processes using 2D representations struggled to effectively communicate the visual impact and spatial relationships of proposed developments to stakeholders and the public.To address these issues and revitalize the city centre, Nottingham City Council embarked on an ambitious plan to modernize its urban planning processes. This initiative aimed to enhance transparency, efficiency, and public engagement in planning decisions.

Objective

The primary objective of Nottingham's 3D digital twin initiative was to create a comprehensive digital representation of the city to support more efficient, transparent, and inclusive urban planning processes. Building on nearly two decades of 3D modelling experience that began with mapping the city's 850 underground caves, the project aimed to address key challenges in development management and community engagement.

(continued)

Case study: Nottingham 3D digital twin, UK

The key objectives of the project were to promote efficiency, transparency, and improve the quality of urban infrastructure planning. Creating a digital twin of Nottingham could support multiple users across various applications:

- **Development management**: Planners needed to assess the visual impact, calculate site capacity, and negotiate height and floor space with developers for major planning applications more effectively.
- **Public engagement**: The city required tools to make complex spatial information accessible to citizens, particularly younger demographics, to improve participation in planning processes.
- **Investment promotion**: City leaders needed a platform to showcase development opportunities and attract investment to support urban regeneration goals.
- **Heritage protection**: The city needed to integrate conservation areas, listed buildings, and the unique cave network into planning considerations.
- **Sustainability**: Planners required capabilities to assess environmental impacts, including biodiversity net gain requirements and carbon neutrality goals by 2028.

Solution approach

Nottingham's 3D digital twin is a council-led programme developed by the City's GIS team in partnership with Esri (ArcGIS Urban platform), Bluesky International (MetroVista data capture), and the University of Nottingham. The project received significant government support, including GBP 375 000 from the Ministry of Housing, Communities and Local Government's PropTech Innovation Fund Round 3, as part of a broader GBP 3.2 million national initiative involving 27 local planning authorities.[31]

The solution is built upon Geographic Information System (GIS) technology, specifically ArcGIS Urban, which allows for the creation and analysis of 3D urban models on a shared platform. The digital twin covers more than 73 square kilometers and depicts thousands of historic and modern buildings, open spaces, and infrastructure.[32] The technical foundation combines multiple data sources: high-resolution aerial imagery and oblique photographs captured using Leica CityMapper sensors, LiDAR data with point densities up to 30 points per square metre, and photogrammetric 3D building models.[33]

A core component of the project was creating a comprehensive data model that integrates various urban datasets. The platform incorporates conservation areas, flood risk zones, heritage sites, live traffic data, and CCTV feeds into a unified 3D environment.[34] Bluesky International's MetroVista technology provides photorealistic mesh models that combine ultra-high resolution aerial photography with high-density LiDAR to create accurate citywide representations.[35]

The system allows planners to import detailed 3D models provided by architects and developers directly into the city's digital twin, enabling instant visualization of how proposed developments will integrate within the existing urban environment.[36] This capability has become embedded in Nottingham's workflow for assessing major planning applications, with 3D modelling now a fundamental part of the pre-application process.[37]

The University of Nottingham contributed innovative engagement tools, including a Projection Augmented Relief Model (PARM) that projects digital data onto a physical 3D model of the city centre, making planning information accessible to non-technical audiences. The project also explores augmented reality (AR) and virtual reality (VR) applications to enhance stakeholder engagement.[38]

(continued)

Case study: Nottingham 3D digital twin, UK

Results

The implementation of Nottingham's 3D digital twin has delivered significant quantifiable outcomes across multiple domains:

- **Investment attraction**: The platform has played a key role in unlocking more than GBP 4 billion in investment for city redevelopment projects. Notable developments include the renovation of the train station, a new bus station and parking garage, the creation of the Green Heart Park, and the Island Quarter development, which includes 300 homes and housing for Nottingham University students.[39]
- **Planning efficiency**: The implementation of the digital twin has significantly improved Nottingham's urban planning processes. It has streamlined planning workflows, reduced decision-making time, and enhanced communication across sectors. A cost-benefit analysis conducted as part of the PropTech Innovation Fund found that for every GBP invested in digital twin technology, local planning authorities can expect GBP 2 in efficiency savings and benefits over a 10-year period.[40]
- **Public recognition**: In 2024, the project won the Geography in Government Award for Innovation, with the "City as Lab" initiative being named Overall Winner across all categories.[41]
- **Knowledge transfer**: Nottingham has successfully supported Bradford City Council in developing similar capabilities and created a blueprint for other local authorities to replicate the approach.[42]

Lessons learned

- **Stakeholder integration**: The success of the digital twin relied on strong partnerships between city government, technology providers (Esri, Bluesky International), academic institutions (University of Nottingham), and development community engagement throughout the implementation process.
- **3D Data quality and integration**: High-resolution, accurate 3D data proved essential for stakeholder confidence and decision making. The combination of photorealistic mesh models with traditional 3D building data provided the right balance of visual appeal and technical accuracy for different audiences.
- **Workflow embedding**: The most significant benefits emerged when 3D modelling became integrated into standard planning processes rather than remaining a separate visualization tool. Making 3D model submissions mandatory for major applications ensured consistent adoption.
- **Multiplatform accessibility**: Success required ensuring the digital twin was accessible across devices and skill levels, from professional planners using detailed analytical tools to public engagement through simplified web interfaces and physical models.
- **Continuous development**: The project demonstrated the importance of iterative improvement and expansion, with ongoing enhancements funded through subsequent government grants and integration of new technologies like AR and VR.

Conclusion

Nottingham City Council's development of a 3D digital twin has transformed its approach to urban planning, making it more efficient, transparent, and inclusive. The integration of geospatial data and XR visualization has not only improved planning outcomes but also fostered greater public engagement and unlocked substantial investment for city redevelopment. This initiative positions Nottingham as a leader in the adoption of digital technologies for urban planning.

Use case 8: Climateverse for sustainable storytelling (Horizon 3)

Description

This use-case as horizon-3 category describes the establishment of a future citizen-centric virtual environment for climate transition of urban spaces; for example, on a neighbourhood or district level: Building a virtual climate image, real laboratory and playful incentive systems for the transfer of knowledge, and participation for a multitude and high complexity of stakeholder interests.

An application could be an interactive, virtual cityscape as classroom that teaches fundamental concepts of sustainable development. Topics such as climate change, resource management, and social justice are vividly experienced in an open and interoperable urban 3D environment. The use-case could be extended with participatory crowdfunding of climate-mitigation measures in urban spaces.

Impacts

1) **Behavioural citizen transformation**: Virtual interaction with climate scenarios empowers citizens to adopt sustainable practices by directly visualizing the impact of their personal choices on neighbourhood resilience.
2) **Immersive climate awareness**: The 3D virtual environment allows citizens to experience future climate projections firsthand, transforming abstract climate data into visceral, personal understanding that motivates collective action.
3) **Participatory urban planning**: Citizens become active co-designers of their neighbourhoods by experimenting with different climate solutions in the virtual space, democratizing the urban planning process and generating community-supported climate initiatives.
4) **Inclusive social climate justice modelling**: the use case ensures equity by highlighting disproportionate climate impacts on vulnerable populations and prioritizing solutions that provide fair distribution of climate burdens and benefits across all community.

Key beneficiaries

- Citizens and non-profit associations on neighbourhood level
- Urban and regional planners

- Local government authorities
- Developers and infrastructure investors
- Community organizations and residents
- Architects and urban designers
- Educational Institutions
- Environmental and transport agencies

Key technologies

- **Digital twin**: Provides accurate real-time virtual replicas of neighbourhoods with embedded climate data, creating the foundation for evidence-based planning scenarios.
- **Metaverse**: Creates a persistent, shared virtual space where citizens, educators and planners can collaborate on climate solutions regardless of physical location.
- **AR/VR/MR**: Enables immersive experiences that let users physically interact with climate projections, making abstract environmental concepts tangible and emotionally resonant.
- **IoT**: Feeds live environmental measurements into the digital twin, ensuring planning decisions reflect current conditions and tracking the real-world impact of implemented solutions.

SDG alignment

- **SDG4: 4: Target 4.7** By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development
- **SDG 13: Target 13.3** Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning

Risk level

Table 8: Risk level: Climateverse for sustainable storytelling

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	Collaborative sustainability planning increases public safety and reduces climate risks.
Stakeholder acceptance	Low	Medium	High	It takes an integrated and profound approach in combining the Climateverse with the multi-ple stakeholder interests on urban level.
Data privacy and security	Low	Medium	High	Sustainability data is mostly open, accessible and with low risk for data privacy concerns.

Table 8: Risk level: Climateverse for sustainable storytelling (continued)

Risk attribute	Risk rating			Explanation
Financial/ operational	Low	Medium	High	Classified as medium due to operating costs and efforts for keeping sustainability data up-to-date.

Implemented in:

Arctic Basecamp Pavilion, World Economic Forum's Global Collaboration Village (2024)

The use case has not yet been identified at the city-level, first pilots are expected to come in the near future.

Case study: Arctic Basecamp Pavilion, Global Collaboration Village, World Economic Forum

Context

The accelerating thaw of the Arctic is one of the planet's most urgent warning signals, with melting ice sheets, permafrost thaw, and rising sea levels carrying profound global implications.

Yet, decision-makers and stakeholders far from polar regions often struggle to grasp the scale and immediacy of these risks. Traditional reports and charts, while scientifically accurate, fail to generate the emotional resonance needed to spur urgent climate action. World Economic Forum's Global Collaboration Village[43] developed a virtual pavilion to bring the Arctic's climate realities directly into high-level global discussions.

Objective

The primary objective of the Arctic Basecamp Pavilion was to transform abstract climate data into tangible, emotionally engaging experiences for global leaders. Specific goals included:

- Raising awareness of Arctic climate tipping points and their cascading global effects.
- Empowering decision-makers to connect scientific data with strategic policy conversations.
- Demonstrating the power of immersive storytelling to strengthen climate risk communication.
- Providing a trusted environment where science could be experienced, not just read.

Solution approach

The Pavilion recreated Arctic environments in an immersive 3D space within the Global Collaboration Village. Participants could virtually stand on ice sheets, witness melt patterns, and explore real-time scientific visualizations of sea-level rise and global feedback loops. By integrating live climate data and scenario projections, the Pavilion offered both emotional immersion and scientific rigor.

During the 2024 World Economic Forum Annual Meeting in Davos, the Pavilion became a focal point for climate risk discussions. Leaders and stakeholders explored the simulations in real time, enabling dialogue grounded in visualized evidence rather than static charts. The Pavilion provided a shared spatial environment where policymakers, scientists, and industry leaders could align around the urgency of Arctic change.

(continued)

Case study: Arctic Basecamp Pavilion, Global Collaboration Village, World Economic Forum

Results

The Pavilion delivered significant outcomes in climate communication and engagement:

- **Enhanced Awareness**: The participants reported a clearer understanding of climate risk after engaging with immersive climate hubs, including the Arctic Basecamp Pavilion.
- **Emotional Impact**: By virtually placing leaders on Arctic ice, the Pavilion turned abstract datasets into lived experiences, making the urgency of Arctic melt tangible.
- **Policy Dialogue**: The Pavilion's immersive storytelling helped bring Arctic science directly into high-stakes policy discussions, influencing how participants perceived global climate risks.
- **Visibility**: The Pavilion highlighted the role of immersive XR platforms as powerful tools for communicating science to diverse stakeholders.

Lessons learned

- **Immersion Drives Urgency**: Abstract climate data gains greater traction when experienced in spatial, emotionally resonant environments.
- **Partnerships Matter**: Collaboration between science communicators (Arctic Basecamp), global conveners (WEF), and technology providers (Accenture, Microsoft) was essential to ensure both credibility and reach.
- **Scalability Potential**: While piloted at a global summit, the model can be adapted to local contexts (e.g., cities or neighbourhoods) to raise awareness and support participatory climate action.

Conclusion

The Arctic Basecamp Pavilion exemplifies how immersive technologies can reshape climate risk communication. By combining cutting-edge XR visualization with rigorous science, it enabled global leaders to experience the Arctic's fragility firsthand, fostering empathy, urgency, and informed decision-making. As part of the Global Collaboration Village, this initiative illustrates how a Climateverse could use immersive storytelling to transform abstract data into shared understanding, strengthening citizen engagement and policy action on climate change.

Use case 9: Nature-centric digital planning (Horizon 1)

Description

Nature-centric and biophilic digital planning uses virtual world technologies such as digital twins, AI-driven simulations, and augmented reality to design, monitor and optimize urban green infrastructure. By integrating ecological modelling with high-resolution geospatial data, city planners, environmental agencies and community stakeholders can explore how biodiversity corridors, urban forests, wetlands, and other nature-based solutions (NBS) contribute to urban resilience and sustainability. For instance, a digital twin of an urban watershed can model how green roofs and permeable surfaces reduce flood risk, filter pollutants, or preserve local biodiversity.

Sensor networks (IoT) feed real-time data on soil moisture, carbon sequestration rates, and habitat use into these digital platforms and help to identify ecosystem service "hotspots" and related climate vulnerabilities. AI and machine learning can then run scenario analyses by, for example, anticipating the impact of future extreme weather events or pollution levels on plant and animal populations. They help by providing evidence-based guidance for policy interventions. AR/VR environments help planners and citizens visualize proposed green infrastructure changes in 3D, and can support inclusive public engagement and participatory decision making. This approach can support quantifiable planning for goals along the three-bottom-line thinking of sustainability of social, ecological, and economic aspects of urban life; for example, through cooler microclimates and better air quality to enhance biodiversity and increase property values.

Impacts

1) **Urban resilience**: By integrating NSB data into digital planning, cities can better mitigate flooding, heatwaves and other climate risks. This is grounded in scientific evidence linking vegetation cover to lowered urban heat island effects and reduced stormwater run-off.
2) **Ecological diversity**: Restored habitats and green corridors foster biodiversity, supporting pollinators, birds, and local flora. Accurate virtual modelling helps identify the best locations for ecological restoration and helps protecting species' migratory and feeding pathways.
3) **Community well-being**: Access to green spaces improves mental and physical health. With advanced visualization, citizens can understand and support green infrastructure projects, and strengthen social cohesion and sense of place.
4) **Economic value**: Well-planned ecological features can reduce infrastructure costs (e.g., stormwater systems) and increase property values. Digital scenario tools may reduce planning uncertainties, and possibly lower long-term municipal expenditures.
5) **Regulatory compliance**: Ensures projects meet environmental and urban planning regulations, this is supported by transparent data, predictive modelling, and measurable ecosystem-service outcomes.

Key beneficiaries

- Urban planning departments and environmental agencies
- Local communities (e.g., residents, schools, neighbourhood associations)
- Urban ecologists, landscape architects, and civil engineers
- Real-estate developers seeking nature-aligned projects
- NGOs focused on environmental conservation and community well-being
- Utility companies managing stormwater and water resources

Key technologies

- **Digital twins**: Create 3D dynamic models of urban ecosystems, integrating geospatial, climatic, and ecological datasets to simulate and visualize environment–infrastructure interactions.
- **IoT Networks**: Sensor arrays measure soil humidity, water quality, plant phenology, and wildlife presence in real time, transmitting data to digital twin dashboards.
- **AI & machine learning**: Analyse large ecological and climatic datasets to identify optimal NBS interventions, predict carbon sequestration potential, or forecast climate-change impact. Automate scenario simulations and propose multibenefit solutions (e.g., balancing biodiversity goals with flood mitigation) across complex urban ecosystems.
- **AR/VR/MR**: Engage citizens in immersive "walkthroughs" of proposed greening initiatives; help fieldworkers identify species and measure vegetation health.

SDG alignment

- **SDG 11: Target 11.3** By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries
- **SDG 11: Target 11.6** By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management
- **SDG11: Target 11.7** By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older people and people with disabilities
- **SDG 13: Target 13.2** Integrate climate change measures into national policies, strategies and planning
- **SDG 15: 15.5** Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect, and prevent the extinction of, threatened species
- **SDG 15: Target 15.9** By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts

Risk level

Copy the risk ratings from the PPT template and, in the final column, provide an explanation of the risk rating given to each risk attribute:

Table 9: Risk level: Nature-centric digital planning

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	NBS interventions can reduce climate risks (flooding, heat waves), but potential confusion over digital modelling and actual field conditions requires consistent data availability and consistent monitoring to ensure public safety benefits are realized.
Stakeholder acceptance	Low	Medium	High	While many communities value green infrastructure, some residents or developers may resist changes in land use. Open, transparent data-sharing and early engagement can mitigate reluctance to adopt NBS.
Data privacy and security	Low	Medium	High	Ecological and location-based data are generally less sensitive than personal data. Real-time sensor networks or user-generated inputs can present privacy concerns. Ensuring cybersecurity and data governance frameworks is necessary.
Financial/ operational	Low	Medium	High	Upfront investment in sensors, AI modelling, and cross-departmental coordination is significant. Ongoing maintenance of data sources, digital twins and sensor networks requires stable governance and funding arrangements.

Implemented in:

Helsinki, Finland; Tallinn, Estonia: Boston, USA; Stuttgart, Germany

Case study: Herbarium.ai implementation in Tallinn

Context

Herbarium.ai's efforts in Helsinki and Tallinn were part of the GreenTwins project, which aimed to enhance urban greenery planning through digital models. Both cities developed existing Urban Digital Twins, although these primarily for built structures rather than urban nature. The GreenTwins initiative sought to address this gap by integrating high-resolution vegetation data to inform professional planners and the public.

In Helsinki, authorities had already begun mapping approx. 230 000 urban trees using two-dimensional data, while Tallinn was exploring ways to promote public participation in green space planning. Herbarium.ai contributed botanical expertise, digital modelling, and visualization tools. It aims at expanding the utility of each city's Urban Digital Twin beyond infrastructure planning to include ecosystem assessments.[44]

Objective

The primary objective was to provide urban planners, citizens, and other stakeholders with accurate, visually detailed representations of plant species and seasonal changes within urban environments. By consolidating diverse datasets, the project aimed to create a robust planning ecosystem that supports informed land-use decisions, optimizes green space distribution, and encourages citizen engagement. This was to be achieved by:

- Generating a science-based 3D vegetation library and seasonal growth model for Tallinn and Helsinki.
- Integrating that library into each city's digital-twin platform and zoning workflows.
- Supplying planners with metrics on shade, solar gain and habitat connectivity, while giving citizens intuitive XR apps to co-design local greenery.[45]

Solution approach

The consortium delivered three tightly linked components:

- **Herbarium.ai species library** – 73 locally common trees, shrubs and perennials captured as low-poly, BIM-ready 3D objects with parametric attributes (height, crown spread, leaf area) and phenological states (spring foliage, flowering, autumn colour).
- **Smart City Planning Hub (Tallinn)** – an on-site exhibition and co-creation space equipped with power-walls and VR headsets where planners, developers and residents test greening scenarios together.
- **Tool-chain for professionals & public:**
  - **Virtual Green Planner (VGP)** – a browser-based editor that lets planners drop Herbarium.ai objects into the city mesh, run solar-radiation and shade analyses, and export compliance reports.
  - **Urban Tempo (UT)** – an AR mobile app that overlays seasonally correct vegetation on real streets so users can preview growth over 30 years and vote on their preferred layout.

Additionally, Helsinki incorporated detailed data on its urban trees into its 3D city model. This allowed simulations and analyses of microclimate, canopy coverage, and solar radiation, to guide sustainable urban development. Data flows through open APIs: field inventories and LiDAR feeds update canopy height; VGP writes changes back to the central CityGML store; UT streams the same JSON to smartphones. All assets observe a shared taxonomy and metadata scheme, enabling cross-border re-use between Helsinki and Tallinn.[46]

(continued)

Case study: Herbarium.ai implementation in Tallinn

Results

- **Enhanced Planning Accuracy**: The 3D vegetation models and integrated datasets improved the spatial and temporal precision of urban greenery planning.
- **Public Participation**: The tools fostered citizen collaboration, enabling community input on local vegetation designs and land-use proposals.
- **Data-Driven Assessments**: Analysis of environmental variables (e.g., tree canopy coverage, microclimate effects) yielded evidence-based recommendations for green infrastructure upgrades.
- **Scalable Framework**: The methodologies can be adapted for broader use in other cities seeking to integrate vegetation data into digital twins.[47]

Lessons learned

- **Data standardization**: Consistent taxonomies and metadata standards facilitated interoperability among various GIS and digital twin platforms.
- **Stakeholder engagement**: Early involvement of citizens and professionals, supported by intuitive visualization tools, increased acceptance and relevance of the planning outcomes.
- **Technological interoperability**: Integrating AI-generated 3D vegetation models into existing city models required functioning APIs and well-structured data pipelines.
- **Maintenance requirements**: Ongoing data updates, especially for dynamic elements like plant growth or seasonal changes, demand dedicated resources and clear workflows.[48]

Conclusion

Nature-centric digital planning proves that urban greenery can be fully integrated into digital twins and decision-support systems. In Tallinn and Helsinki, the Herbarium.ai and GreenTwins projects show how 3D plant modelling, AI analysis of ecosystem services, and AR/VR interfaces help ecological features to play a role in city design. Planners, citizens, and policymakers can collaboratively shape green neighbourhoods with tangible, data-backed forecasts. In the examples, this leads to higher public support and better environmental outcomes. The solution requires upfront investment for data collection, software development, and training. The long-term returns are notable through the benefits green infrastructure can provide.[49]

Use case 10: Virtual Urban Placemaking (Horizon 1)

Description

AR/VR-driven digital twin and metaverse urban placemaking is an emerging approach that uses immersive technologies to enhance how people experience, interact with, and shape, urban spaces. By creating detailed virtual replicas of real-world environments, cities can offer new layers of engagement, ranging from virtual tourism and cultural programming to participatory planning and augmented public art.

These technologies enable physical and digital participation in placemaking, allowing communities, artists and planners to co-create dynamic, inclusive urban experiences that transcend geographic and social boundaries, while also supporting innovation, sustainability and cultural expression in the built environment. Core components of this use case are:

- Presence & belonging: Immersive tech deepens emotional connections to place.

- Co-creation: artists and citizens shape the virtual layers.
- Continuity: Hybrid virtual-physical events extend the urban experience across time and space.
- Accessibility: The digital twin opens up the city to anyone, anywhere.

Impacts

1) **Civic engagement and inclusion**: By enabling remote participation and storytelling by local communities, this use case democratizes access to cultural and urban development processes.
2) **Economic activation**: Virtual environments can attract digital tourism, promote local businesses, and generate new revenue models through licensing, sponsorship, or branded content.
3) **Cultural preservation and innovation**: Digitally archiving urban heritage allows for its reinvention in interactive formats while preserving cultural memory.
4) **Sustainable urban planning**: Digital twins can be used in planning simulations, allowing stakeholders to evaluate and visualize urban changes with minimal environmental impact.
5) **Education and awareness**: Immersive educational layers can highlight environmental, historical or social dimensions of a city, so improving public awareness and literacy.

Key beneficiaries

- City residents and communities
- Tourists and virtual visitors
- Local artists and creative professionals
- Urban planners and architects
- Municipal and cultural policymakers
- Event organizers and festival producers
- Private sector partners (tech, real estate, retail)

Key technologies

- **Digital twin technology**: High-fidelity 3D models of the urban environment, used for simulation, visualization and interaction.
- **Virtual reality (VR)**: Enables fully immersive experiences of urban space for remote or gamified exploration.
- **Augmented reality (AR)**: Overlays digital content onto the physical cityscape, allowing real-world engagement through mobile devices or AR glasses.
- **Metaverse platforms**: Persistent, social, and programmable environments for events, commerce and public participation.
- **5G connectivity**: Supports real-time data transmission and synchronized AR/VR experiences in public space.
- **Artificial intelligence (AI)**: Used to personalize user experiences, generate content or support simulations.

SDG alignment

- **SDG 8: Target 8.9** By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products
- **SDG 9: Target 9.1** Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all
- **SDG 11: Target 11.3** By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries
- **SDG 11: Target 11.4** Strengthen efforts to protect and safeguard the world's cultural and natural heritage
- **SDG 17: Target 17.17** Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually agreed

Risk level

Table 10: Risk level: Virtual Urban Placemaking

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	Experiences are digital or augment low-risk urban environments.
Stakeholder acceptance	Low	Medium	High	Requires digital literacy and buy-in from traditional urban stakeholders.
Data privacy and security	Low	Medium	High	Geolocation and personal data require strict governance and cybersecurity.
Financial/ operational	Low	Medium	High	Requires upfront investment in 3D modelling, platforms, and public promotion.

Implemented in:

Helsinki, Finland; Seoul, Republic of Korea (Seoul Smart City AR pilot); Singapore (Virtual Singapore project); Rotterdam, Netherlands (digital twin for urban planning + cultural layers)

Case study: Placemaking in Virtual Helsinki

Context

Cities worldwide are increasingly exploring citiverse technologies to enhance urban engagement, tourism, sustainability and innovation. Known for its forward-thinking smart city strategies, Helsinki aimed to re-imagine how residents and international audiences could experience the city's rich culture and architecture through immersive technologies.

Helsinki faced the dual challenge of over-tourism pre-pandemic and a sudden halt in international travel due to COVID-19, emphasizing the need for sustainable alternatives to traditional tourism and new forms of civic engagement. The city also aimed to boost its creative technology industries and project itself as a leader in immersive media.[50]

Anchored in its 2021–2025 City Strategy, *A Place of Growth*, Helsinki has committed to pursuing sustainable development that enhances **social, economic, and cultural wellbeing** across all demographics. The City's Culture and Leisure Division, in particular, identified key priorities: supporting children's culture, improving inclusion and access for elderly residents, advancing digital services for cultural participation, and fostering equity in all cultural offerings.[51] A dedicated allocation of **EUR 8 million** was earmarked specifically to **rebuild the cultural sector**, recognising the deep impacts of the COVID-19 crisis on artists, institutions, and audiences.[52]

As part of this, the City of Helsinki launched "Virtual Helsinki", a 3D digital twin of the city that enables virtual exploration, cultural attendance and participatory urban planning through XR (extended reality) environments. With growing interest in immersive media and sustainable tourism, Helsinki seized the opportunity to position itself as a digital pioneer.

(continued)

Case study: Placemaking in Virtual Helsinki

Objective

The aim of this initiative was to create a photorealistic digital twin of Helsinki that serves as a global platform for cultural events, virtual tourism, and participatory urban engagement, so enabling local citizens and international users to experience and shape the city remotely. The objectives included:

- Offering a sustainable alternative to physical tourism by providing immersive travel experiences and supporting Helsinki's vision for a carbon neutral city by 2035.[53]
- Establish a global stage for Helsinki's cultural institutions, creative talent and festivals.
- Explore and text XR and metaverse technologies to inform future digital strategies
- Enable broad civic participation through immersive digital tools.

Solution approach

Virtual Helsinki's solution is the result of an ambitious partnership between the City of Helsinki and the XR studio Zoan, supported by a diverse ecosystem of city agencies, creative partners, and technology providers. At its core, the initiative involved building a highly realistic digital twin of Helsinki using Unreal Engine as the technical foundation. The development process began with the use of open 3D city data provided by the municipality, which was extensively combined with bespoke hand-crafted modelling, photogrammetry, and photographic textures to accurately simulate key locations such as Senate Square, the iconic White Church, the home and studio of Alvar Aalto, Lonna Island, and other architectural landmarks.[54] An **international team** of more than 35 people worked over three years to create **the most realistic, high-quality sound and visual landscape**.[55]

Accessibility and inclusivity were key design pillars: the digital twin can be explored using a variety of platforms including VR headsets, computers, tablets, and smartphones, minimizing technical barriers. Virtual Helsinki was conceived expressly to ensure that virtual experiences – from guided city tours to interactive exhibits and live concerts – would be available to as many people as possible.[56] Furthermore, Virtual Helsinki supports the city's sustainable tourism goals, making the experience of Helsinki's culture, history and urban life accessible beyond physical boundaries and without carbon-intensive travel, providing a model for digital placemaking in the era of climate consciousness.

A major innovation was the integration of real-time social and cultural programming within the virtual city, exemplified by the highly publicized May Day ("Vappu") celebrations during the COVID-19 pandemic. Rather than cancel the traditional event, Helsinki held immersive concerts with celebrity artists such as JVG, hosted in a virtual Senate Square. These concerts enabled more than 1 million viewers – including 150 000 users creating personal avatars – to participate, cheer, and interact with performers remotely, all within the digital twin.[57] The event was designed to mirror gaming worlds like Fortnite, using Zoan's Burst Live technology to support live interaction and user engagement without requiring a VR headset. The programming also extended to virtual art tours, virtual shopping experiences, and co-creation opportunities for artists and citizens – activities that not only promoted safe social gathering during lockdown but also democratized access to the city's cultural sites.

(continued)

Case study: Placemaking in Virtual Helsinki

The platform adopted an expandable, modular approach: new destinations can be added as the user base and city ambitions evolve. The ZOAN team initially modelled only a few of the central locations of the city: the prominent Senate Square, the iconic Helsinki Cathedral, the home of the legendary architect Alvar Aalto and the Lonna Island. Since then, the experience has expanded to include more than 30 different productions: the virtual exhibition at Amos Rex, the Helsinki Biennial Facebook Open Arts VR experience, and several virtual conferences held at Finlandia Hall.

Results

- Helsinki became a global reference for immersive smart city placemaking.
- Enabled new cultural tourism models, especially during travel restrictions (e.g., during COVID-19) with more than 1 million viewers of the May Day celebrations and 150 000 users creating avatars.
- Increased visibility and engagement for local cultural institutions.[58]
- Fostered a digital ecosystem around XR technologies and creative industries.
- Received international media attention, boosting city branding and innovation reputation.

Lessons learned

- **Cross-sector partnerships**: Successful implementation of Virtual Helsinki relied heavily on strong collaboration across multiple sectors, including municipal government, technology providers, and creative industries. Establishing clear roles and fostering ongoing cooperation between city authorities, XR studios like Zoan, and local artists was fundamental to delivering an engaging and sustainable digital twin platform.
- **User engagement and education**: Public understanding of the purpose of Virtual Helsinki and how to participate effectively emerged as a critical factor. Simplified onboarding processes and accessible educational materials helped lower barriers for diverse audiences. This proactive engagement was essential to maximize user adoption and meaningful interaction with the platform's cultural content.
- **Iterative development and content refreshment**: Continuous improvement through iterative updates and expanding cultural programming proved necessary to maintain relevance and user interest over time. Static digital twins quickly lose appeal; consequently, recurring content cycles, seasonal events and co-created user experiences were integrated to keep the platform dynamic and responsive to community needs.
- **Hybrid Physical-Digital Integration**: Combining virtual experiences with physical city festivals and events such as Helsinki Design Week, was shown to effectively broaden accessibility and ensure continuity of cultural engagement. These hybrid formats enabled simultaneous participation for remote and onsite audiences, reinforcing inclusivity and sustaining long-term interest in the digital twin.

Conclusion

Virtual Helsinki demonstrates how AR/VR-driven digital twins and metaverse platforms can re-imagine urban placemaking in ways that are participatory, sustainable and globally accessible. By blending cultural heritage, technology, and citizen engagement, the project offers a powerful blueprint for future-ready cities embracing the next wave of immersive urban experiences.

About the Global Initiative on Virtual Worlds and AI – *Discovering the Citiverse*

Launched by ITU, UNICC, and Digital Dubai, the Global Initiative on Virtual Worlds and AI – *Discovering the Citiverse* is a multistakeholder platform dedicated to shaping the next generation of AI-powered virtual worlds[59].

These immersive digital environments are transforming how people live, learn, govern, and interact. The Initiative ensures that AI-powered virtual worlds evolve in ways that are inclusive, interoperable, and human-centric–and that they help deliver on the Pact for the Future and its Global Digital Compact.

Serving as a neutral and action-oriented platform, the Initiative brings together cities, governments, UN agencies, private sector companies, academia, and civil society to collaboratively shape the responsible development and deployment of these technologies.

The Initiative advances its mission through three strategic pillars, each supported by dedicated tracks that address the most urgent challenges and promising opportunities in AI-powered virtual worlds. This comprehensive structure enables the Initiative to deliver both high-level global guidance and practical implementation in cities worldwide.

The Initiative is supported by over 70 international partners.

For more information, please visit: https://www.itu.int/metaverse/virtual-worlds/.

Meet the Champions

Champions are entities that demonstrate leadership by providing financial contributions in support of the Initiative. This may include funding for events, challenges, research outputs, communication activities, trainings, travel grants, or other related efforts.

Ministry of Internal Affairs and Communications

دبي الرقمية
DIGITAL DUBAI

Meet the Founding Partners

Founding Partners are the organizations that launched the Initiative. They serve as the core convening entities and contribute to shaping its long-term vision. The Founding Partners are:

ITU

UNICC

دبي الرقمية
DIGITAL DUBAI

Meet the Supporters

Supporters are organizations that have expressed endorsement of the Initiative and actively participate in its activities. This includes, but is not limited to, participation in tracks, contribution of use cases, co-organization of events, provision of expertise, or public advocacy of the Initiative.

MINISTRY OF INFORMATION, COMMUNICATIONS AND THE DIGITAL ECONOMY

ETRI

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References

1 Utility Strike Avoidance Group (2016) 2014 Utility Strike Damages Report

2 Informatie Vlaanderen (2021) KLIP goes Digital

3 Government Digital Service, Geospatial Commission, and the Department for Science, Innovation and Technology (2024) Policy Paper: National Underground Asset Register project update – November 2024

4 Freeborough *et al.* (On behalf of the Iceberg Industry Group) (2019) National Underground Assets and Subsurface Data: Review of use case applications.

5 Neil Brammer (2024) An Introduction to the NUAR Data Model

6 Government Digital Service, Geospatial Commission, and the Department for Science, Innovation and Technology (2024) Policy Paper: National Underground Asset Register project update – November 2024

7 Government Digital Service, Geospatial Commission, and the Department for Science, Innovation and Technology (2024) Policy Paper: National Underground Asset Register project update – November 2024 and Geospatial Commission (2022) National Underground Asset Register Project Update

8 Government Digital Service, Geospatial Commission, and the Department for Science, Innovation and Technology (2024) Policy Paper: National Underground Asset Register project update – November 2024

9 Geospatial Commission (2022) National Underground Asset Register Project Update

10 Government Digital Service, Geospatial Commission, and the Department for Science, Innovation and Technology (2024) Policy Paper: National Underground Asset Register project update – November 2024

11 https://digitaltwinhub.co.uk/download/credo-an-overview-executive-summary/

12 https://digitaltwinhub.co.uk/download/credo-an-overview-executive-summary/

13 https://digitaltwinhub.co.uk/download/developing-credo-from-demonstrator-to-a-market-ready-tool/

14 https://digitaltwinhub.co.uk/download/credo-data-sharing-principles-framework-and-architecture/

15 https://digitaltwinhub.co.uk/climate-resilience-demonstrator-credo/credo-asset-risk-tool/

16 Identifying the Expected Impacts of CReDO; Frontier Economics 2022; https://digitaltwinhub.co.uk/download/identifying-the-expected-impacts-of-credo-report/

17 https://burningman.org/news/announcements/welcome-to-the-multiverse/; https://brcvr.org; https://sparklever.se; https://www.vice.com/en/article/akzjwj/inside-the-trippy-heartfelt-world-of-virtual-burning-man; https://journal.burningman.org/2020/09/news/official-announcements/2020-virtual-burn-stats/

18 https://burningman.org/news/announcements/welcome-to-the-multiverse/; https://brcvr.org; https://sparklever.se; https://www.vice.com/en/article/akzjwj/inside-the-trippy

-heartfelt-world-of-virtual-burning-man; https://journal.burningman.org/2020/09/news/official-announcements/2020-virtual-burn-stats/

19 *Ibid*.

20 https://burningman.org/news/announcements/welcome-to-the-multiverse/; https://brcvr.org; https://sparklever.se; https://www.vice.com/en/article/akzjwj/inside-the-trippy-heartfelt-world-of-virtual-burning-man; https://journal.burningman.org/2020/09/news/official-announcements/2020-virtual-burn-stats/

21 *Ibid*.

22 https://www.uia-initiative.eu/en/uia-cities/kerkrade; https://www.superlocal.eu/projecten/super-circular-estate/; https://www.iba-parkstad.com/projecten/super-circular-estate; https://www.tudelft.nl/en/architecture-and-the-built-environment/

23 https://www.uia-initiative.eu/en/uia-cities/kerkrade; https://www.superlocal.eu/projecten/super-circular-estate/; https://www.iba-parkstad.com/projecten/super-circular-estate; https://www.tudelft.nl/en/architecture-and-the-built-environment/

24 *Ibid*.

25 https://www.uia-initiative.eu/en/uia-cities/kerkrade; https://www.superlocal.eu/projecten/super-circular-estate/; https://www.iba-parkstad.com/projecten/super-circular-estate; https://www.tudelft.nl/en/architecture-and-the-built-environment/

26 *Ibid*.

27 *Ibid*.

28 https://www.arcgis.com/home/item.html?id=fa361ff8d52e446780eccf3932d6c1a0

29 *Ibid*.

30 *Ibid*.

31 https://committee.nottinghamcity.gov.uk/documents/s142875/NCC%203D%20PropTech%20Engagement%20Fund_%20Round%203%20Application%2007022023%20UPDATE.pdf; https://www.esri.com/about/newsroom/blog/nottingham-3d-planning-efficiencies; https://www.arcgis.com/home/item.html?id=fa361ff8d52e446780eccf3932d6c1a0

32 https://digitalplanningdirectory.org/case-studies/accelerating-the-planning-process-with-3d-city-model/

33 https://aag-it.com/connecting-nottingham-the-technology-enhancing-community-engagement/

34 https://resource.esriuk.com/wp-content/uploads/Nottingham-City-Council.pdf

35 https://www.esriuk.com/en-gb/arcgis/products/arcgis-urban/overview

36 https://committee.nottinghamcity.gov.uk/documents/s142875/NCC%203D%20PropTech%20Engagement%20Fund_%20Round%203%20Application%2007022023%20UPDATE.pdf

37 https://3d-hub-nottmcitycouncil.hub.arcgis.com/pages/71bd82245cf246578ace53b92293890b

38 https://www.nottinghamcity.gov.uk/information-for-business/business-information-and-support/procurement/uk-shared-prosperity-fund-ukspf/

[39] https://www.arcgis.com/home/item.html?id=fa361ff8d52e446780eccf3932d6c1a0

[40] *Ibid*.

[41] https://www.nottingham.ac.uk/geography/news-items/2024/city-as-lab-collaboration-wins-award.aspx

[42] https://mhclgdigital.blog.gov.uk/2025/03/18/funding-boost-to-support-digital-planning-innovation/

[43] https://reports.weforum.org/docs/WEF_Reimagining_Collaboration_in_XR_Lessons_from_the_Global_Collaboration_Village_2025.pdf

[44] https://greentallinn.eu/en/flag-projects/green-twins; https://www.tallinn.ee/en/valisprojektid/greentwins-tallinn-helsinki-digital-green-model; https://finestcentre.eu/smart-services-to-cities/advisory-and-tools/herbarium-ai/; https://www.eea.europa.eu/publications/who-benefits-from-nature-in; https://ocm.iccrom.org/sdgs/sdg-15-life-land/sdg-159-integrate-ecosystem-and-biodiversity-governmental-planning; https://data.taltech.ee/records/ehrhf-3cn55/files/GreenTwinsSummary; https://3diwatermanagement.com/case/rotterdam-truly-a-smart-city/

[45] *Ibid*.

[46] *Ibid*.

[47] https://greentallinn.eu/en/flag-projects/green-twins; https://www.tallinn.ee/en/valisprojektid/greentwins-tallinn-helsinki-digital-green-model; https://finestcentre.eu/smart-services-to-cities/advisory-and-tools/herbarium-ai/; https://www.eea.europa.eu/publications/who-benefits-from-nature-in; https://ocm.iccrom.org/sdgs/sdg-15-life-land/sdg-159-integrate-ecosystem-and-biodiversity-governmental-planning; https://data.taltech.ee/records/ehrhf-3cn55/files/GreenTwinsSummary; https://3diwatermanagement.com/case/rotterdam-truly-a-smart-city/

[48] *Ibid*.

[49] *Ibid*.

[50] https://www.hel.fi/en/news/helsinki-encourages-safe-remote-may-day-celebrations-may-day-eve-will-culminate-in-the-vapun-paalla

[51] https://www.hel.fi/en/decision-making/decision-making/strategy-and-economy/strategy

[52] https://www.hel.fi/en/news/coronavirus-recovery-aid-has-helped-increase-cultural-events-recreational-groups-and-youth-work

[53] https://carbonneutralcities.org/wpcontent/uploads/2019/06/Carbon_neutral_Helsinki_Action_Plan_1503019_EN.pdf

[54] https://www.ronenbekerman.com/virtual-helsinki-case-study/

[55] https://www.tomorrow.city/helsinki-opening-new-frontiers-in-digital-tourism/

[56] https://www.ronenbekerman.com/virtual-helsinki-case-study/

[57] https://www.hel.fi/en/news/helsinki-encourages-safe-remote-may-day-celebrations-may-day-eve-will-culminate-in-the-vapun-paalla

[58] *Ibid*.

[59] https://www.itu.int/metaverse/virtual-worlds/

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