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

AI-Enabled Citiverse: Use Cases for Cities in the Age of AI

City Administration, Services and Public Participation

Foreword

This publication was developed within the framework of the Global Initiative on AI and Virtual Worlds – *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 advances the development of the AI-enabled citiverse, where artificial intelligence, spatial intelligence, digital twins, and immersive systems converge to deliver real-world impact. It aims to ensure that this transformation is inclusive, trusted and interoperable, and that it serves people, cities and communities.

By connecting cities, governments, industry, academia, and the UN system, the Initiative supports the transition from vision to implementation – empowering leaders to harness these technologies to improve quality of life, strengthen resilience, and drive sustainable and inclusive development.

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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
GenAI	Generative artificial intelligence
GPS	Global positioning system
ICT	Information and communication technology
IoT	Internet of Things
MR	Mixed reality
NIS2	EU Directive on Security of Network and Information Systems 2
ROI	Return on investment
SDG	Sustainable Development Goal
SSC	Smart sustainable city
VR	Virtual reality
XR	Extended reality

Executive Summary

Citizens increasingly expect the same responsiveness from their city government that they experience in other areas of their lives, and trust in public institutions, where it has been hard won, is easily lost. This report examines how AI-enabled citiverse and related technologies are helping cities meet that challenge: delivering services that are faster, more accessible and more attuned to the needs of diverse communities, while opening new channels for the kind of meaningful civic participation that rebuilds the relationship between government and the governed. It is one of five thematic use case reports that collectively constitute the AI-Enabled Citiverse: Use Cases for Cities in the Age of AI. Together, they provide a practical reference for AI-enabled citiverse implementation across major urban domains. Intended for city leaders, policymakers and urban innovation practitioners, it provides a concise overview of applications through which AI-enabled citiverse and related technologies can improve public service delivery, enhance citizen engagement and participation, support more sustainable city operations, and strengthen transparency and accountability, spanning smart waste management, XR-enabled fieldworkers, next generation 311 services, citizen sentiment mapping, virtual town halls, civil servant training, immersive community services, and urban air quality monitoring.

Technology in public administration earns its place only when it makes services genuinely more accessible, institutions more accountable, and the relationship between city and citizen more responsive. Use cases are examined not only in terms of their technological composition, but through the lens of their relevance to service efficiency, public trust, citizen participation, sustainability and implementation readiness.

Who should use this report?

This report is intended for:

- mayors and city leaders;
- national ministers and senior policymakers;
- national regulatory authorities;
- city administrators and public sector leadership teams;
- policy advisers and urban strategy teams;
- digital, innovation, and transformation offices;
- public officials responsible for planning, infrastructure, service delivery, and civic engagement;
- consultancy firms supporting technical, commercial, and strategic decision-making.

How can this report help?

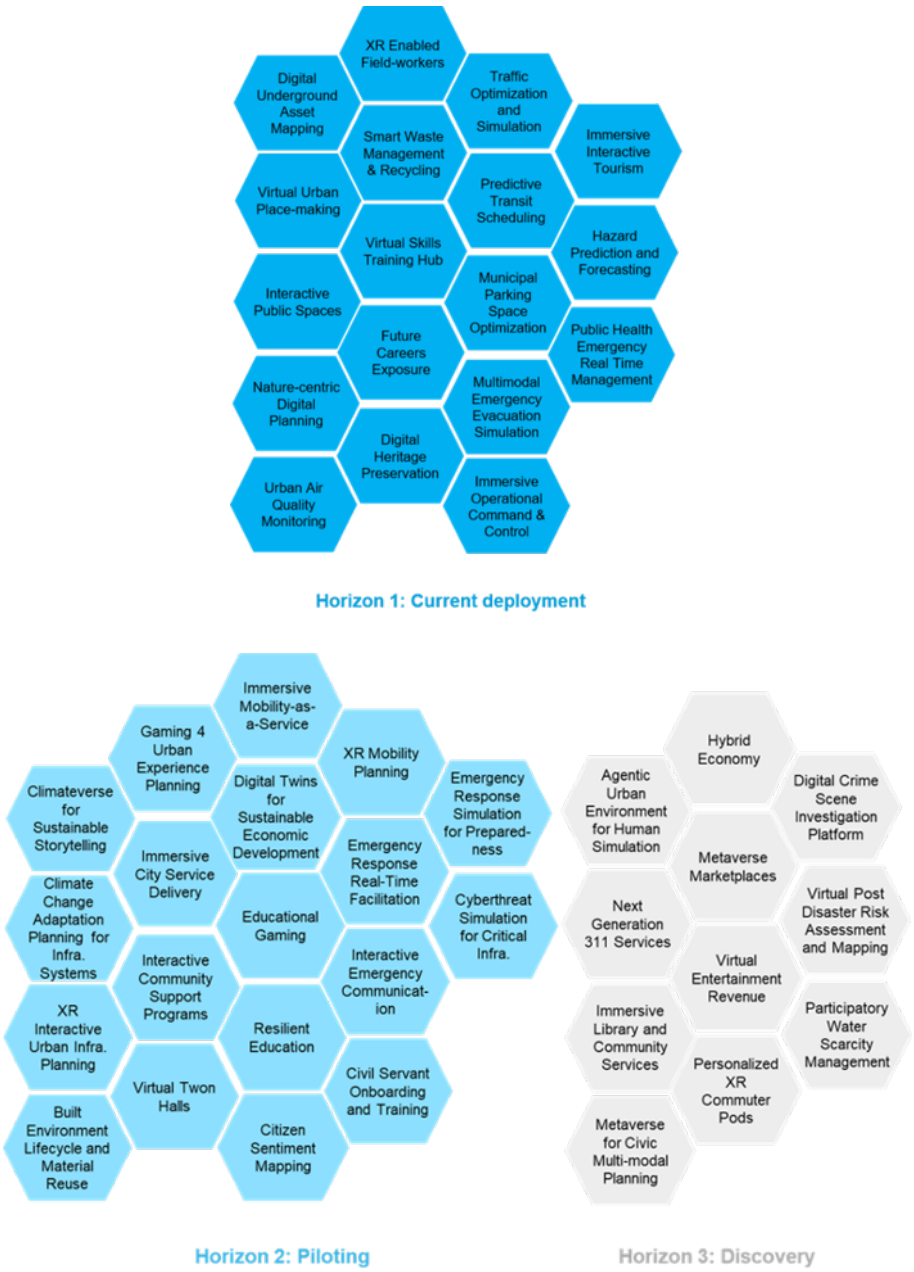
This report is intended to help readers:

- understand the range of use cases through which the AI-enabled citiverse can support city administration, services and public participation;
- explain why those use cases matter, how emerging technologies translate into practical improvements in governance and service delivery, and where their relevance lies for public institutions and communities;
- connect long-term urban transformation goals with practical implementation choices;
- assess use cases in relation to public purpose, service needs, feasibility, scalability and implementation risk;
- support more responsible, inclusive and future-ready approaches to city governance, public services and civic participation.

1 Introduction

The AI-Enabled Citiverse: Use Cases for Cities in the Age of AI provides a consolidated overview of nearly 50 use cases spanning five thematic areas. Figure 1 presents the overall use case landscape and horizon mapping. It highlights the interconnections between domains and demonstrates how emerging technologies can be applied across multiple aspects of urban life. Within this broader framework, this report focuses on the thematic area of city administration, services and public participation. It will discuss key enabling technologies, implementation impacts, and case studies related to this thematic area. The methodology for use case selection can be found in **AI-Enabled Citiverse: Use Cases for Cities in the Age of AI: Introduction**.

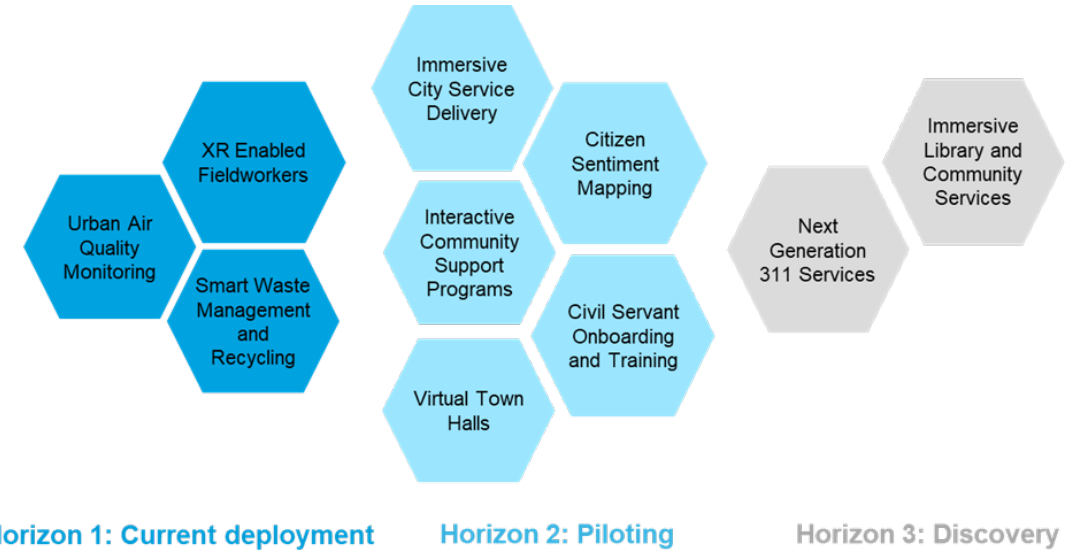
Figure 1: Overall use case overview and horizon mapping



Source: AI-Enabled Citiverse: Use Cases for Cities in the Age of AI: Introduction, 2026

2 City Administration, Services and Public Participation

Figure 2: City Administration, Services and Public Participation Use Case Overview and Horizon Mapping



Source: AI-Enabled Citiverse: Use Cases for Cities in the Age of AI: City Administration, Services and Public Participation, 2026

2.1 Thematic Area Description

Cities are increasingly adopting digital technologies to transform governance, enhance public services, and foster citizen engagement. This is imperative as citizen expectations of public services are rising with citizens expecting seamless, accessible and personalised interaction akin to their engagements with the private sector. Further, OECD's latest research on public trust in institutions highlights that between 2021 and 2023, trust in local government decreased by one or two percentage points on average across countries (OECD 2024).

The city administration, services and public participation thematic area focuses on leveraging digital technologies such as AI, VR, AR, and digital twins, to transform city governance, enhance public services, and foster meaningful citizen engagement. Use cases will span:

- **Public service delivery**: Enhancing access and efficiency in services such as tax management, permit applications, licensing and social support.
- **Citizen engagement, participation and co-creation**: Increasing forums for more inclusive, interactive and meaningful public participation and engagement.
- **Sustainable city operations**: Initiatives to monitor and support the city's transition to Net Zero and promote resource efficiency and circularity for the city and community. This includes a focus on improvements to urban air quality waste management services.
- **Transparency and accountability**: Increasing transparency and citizen oversight into areas such as municipal budgets, service performance and public project updates, in order to build trust and confidence.

The thematic area will prioritise city administration, services and public participation use cases that support the implementation of the SDGS such as Target 11.6 "By 2030, reduce the adverse per capita environmental impacts of cities, including by paying special attention to air quality and other waste management." This thematic area will focus on actionable and scalable solutions

to enhance city governance and services while fostering transparency, efficiency, inclusivity and public trust.

2.2 City administration, services and public participation

Use case 1: Smart waste management and recycling (Horizon 1)

Description

AI-enabled citiverse technologies such as digital twins can be used to create an interactive digital platform for managing urban waste collection and recycling across residential and commercial areas. City stakeholders such as public works departments, sanitation agencies, and environmental planners can use this platform to optimize waste collection routes, monitor recycling rates, track environmental impacts, and allocate resources more efficiently. AI could be leveraged to predict waste generation patterns, automate maintenance schedules, and identify opportunities to improve recycling participation to lower costs and support a transition to a more sustainable, circular economy.

Impacts

1) **Emission reduction**: By optimizing waste collection routes and schedules using AI and real-time digital twin data, the use case significantly reduces fuel consumption of collection vehicles. Fewer truck trips and better route planning lower greenhouse gas emissions and noise pollution.
2) **Quality of life**: Cleaner, well-maintained urban environments result from more efficient waste collection, reducing overflowing bins, litter and unpleasant odours. This leads to reduced vermin attraction and less street congestion from waste trucks, contributing to safer, more pleasant public spaces.
3) **Biodiversity**: Reducing illegal dumping and improving recycling rates decreases pollution and habitat disruption in urban green spaces. Optimized waste collection minimizes the risk of contaminants entering natural ecosystems, supporting urban biodiversity.

4) **Walkability**: By maintaining clean sidewalks and public spaces, and minimizing waste truck presence through dynamic routing, pedestrian-friendly environments are supported. Less traffic from collection vehicles reduces pedestrian exposure to emissions and accidents.
5) **Health and wellbeing**: Lower levels of waste accumulation reduce exposure to harmful bacteria, vermin, and airborne pollutants. Reduced vehicle emissions further improve air quality, contributing to better respiratory and general public health outcomes.
6) **Citizen engagement**: Interactive digital twin platforms empower residents through real-time feedback on recycling participation, waste bin status, and incentives. Gamification and reward schemes increase awareness and motivate behavioural change towards sustainable practices.

Key beneficiaries

- Municipal waste departments
- Citizens & visitors
- Waste collection contractors
- Environmental regulators

Key technologies

- **GenAI**: Generative AI can enhance smart waste management by simulating scenarios, optimizing collection routes, and designing targeted citizen engagement campaigns, even when direct data are limited or changing rapidly. It can also generate accessible, multilingual content and summaries in tools such as digital twins, improving understanding and participation among city staff and residents.
- **AI**: Artificial intelligence can be used to analyse waste generation patterns, forecast peak times for pickup, optimize collection routes, and predict bins likely to overflow or go underutilized. Machine learning can automate scheduling, suggest resource allocation strategies, and continually refine routing as city conditions change.
- **IoT**: Fill-level sensors using ultrasonic, LiDAR, or optical technologies can be embedded in bins to monitor volume, temperature, and tilt status in real time. This enables dynamic data collection on bin usage, reduces manual inspections, and provides immediate insights to waste management operators. These sensors transmit data at frequent intervals and trigger automated alerts for overflows or unusual activity.
- **Computer vision**: Advanced bins can embed cameras and computer vision to automatically recognize and separate recyclables from general waste. Built-in compactors reduce frequency of pickups by compressing materials, and some models gamify recycling by scoring or rewarding proper use.
- **Digital twin**: Digital twins offer a centralized, interactive visualization of all waste assets – mapping sensor data, bin locations, recycled volumes, service schedules, and environmental impacts onto a real-time virtual model of the city. This supports operational efficiency and cross-departmental urban planning, integrating waste flows with other city infrastructure systems.

SDG alignment

- **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 12: SDG 12.5** By 2030, substantially reduce waste generation through prevention, reduction, recycling and re-use

Risk level

Table 1 Risk level: Smart waste management and recycling

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	This use case can increase public health and safety through promoting cleaner homes, streets and public spaces.
Stakeholder acceptance	Low	Medium	High	The risk of stakeholder acceptance is low as residents generally welcome cleaner streets.
Data privacy and security	Low	Medium	High	Data privacy and security risks are low as personal or sensitive data is not included; yet IoT devices and cloud dashboards expand attack surface; NIS2 now designates waste as critical infrastructure
Financial/ operational	Low	Medium	High	Upfront CAPEX for sensors and network, plus change-management costs; ROI depends on fleet size, fuel prices and governance maturity

Implemented in:

Copenhagen, Denmark; Edinburgh, UK; Bratislava, Slovakia; Nicosia, Cyprus; Barcelona, Spain; Singapore; San Francisco, USA; Amsterdam, Netherlands

Case study: A digital twin including waste management in Copenhagen

Context

The city of Copenhagen, Denmark, is advancing its smart city strategy through a comprehensive digital twin project implemented in partnership with Cisco and TDC (Tele Danmark Communications).

As Europe's capital of green digitization, Copenhagen has embarked on an ambitious initiative to create an integrated digital platform that connects and manages data from multiple urban infrastructure systems, including lighting, parking, air quality, and waste management. This project, centred around the Danish Outdoor Living Lab (DOLL) and Copenhagen's "Street Lab," covers a seven-mile (11+ km) urban area in western Copenhagen.

The initiative represents a convergence of more than 40 different smart city solutions deployed as a living laboratory for testing and demonstrating intelligent urban technologies. Copenhagen's commitment to becoming the world's first carbon-neutral capital by 2025 has driven the city to implement data-driven solutions that optimize operations, reduce costs, and improve service delivery while supporting its ambitious climate goals.[1]

Objective

The primary objective of Copenhagen's digital twin initiative was to create a comprehensive, real-time digital representation of urban infrastructure that would support the city's dual goals of operational excellence and environmental sustainability. The project aimed to achieve several key outcomes:

- **Smart city innovation**: Establish Copenhagen as a global leader in smart city technology by creating Europe's largest outdoor testing environment for intelligent urban solutions.[2]
- **Carbon neutrality support**: Develop digital tools and analytics capabilities to monitor, measure, and optimize carbon emissions across city operations, directly supporting Copenhagen's 2025 carbon neutrality target.[3]
- **Operational efficiency**: Implement data-driven decision making across multiple city services, with initial focus on waste management, lighting, parking, and air quality monitoring.[4]
- **Economic growth**: Generate new business models and investment opportunities while reducing operational costs. The broader "Copenhagen Connecting" initiative projects socio-economic benefits of EUR 600 million over its lifetime.[5]
- **Citizen experience**: Enhance quality of life for residents and visitors through more responsive, efficient city services and improved environmental conditions.[6]

Solution approach

Copenhagen's digital twin was implemented through a multilayered architectural approach combining advanced networking infrastructure, IoT sensors, data analytics, and integrated management platforms.

- **Digital infrastructure foundation**: The project established a robust digital backbone utilizing Cisco's Smart+Connected Digital Platform as the core integration layer. This cloud-based system converged data streams from sensors and endpoints across the city, creating an ecosystem of city management applications through open APIs. TDC provided carrier-grade Wi-Fi access and cellular connectivity, ensuring reliable data transmission across the seven-mile test area.[7]
- **Sensor network deployment**: The implementation included a comprehensive IoT sensor network covering multiple urban systems. For waste management specifically, ultrasonic fill-level sensors were deployed in bins throughout the area, measuring volume, temperature, and tilt status in real-time. These sensors transmitted data via Low Power Wide Area Networks (LoRaWAN, NB-IoT) to minimize power consumption while ensuring reliable connectivity.[8]

(continued)

Case study: A digital twin including waste management in Copenhagen

- **Integrated analytics platform**: Data from all connected systems flowed into a centralized analytics platform capable of real-time monitoring and predictive analysis. The system integrated environmental monitoring (air quality, noise, temperature), traffic management, parking sensors, intelligent lighting controls, and waste management data into a single operational view.[9]
- **Waste management integration**: The waste management component utilized smart bin sensors to monitor fill levels and optimize collection routes. When sensors indicated that only 30 per cent of traditional scheduled pickups encountered full bins, the system enabled Copenhagen to transition from fixed schedules to demand-based collection. This data-driven approach was designed to reduce unnecessary collection trips, lower fuel consumption, and decrease CO_2 emissions.[10]
- **Stakeholder engagement**: The project involved extensive collaboration between municipal government (Copenhagen, Frederikssund, and Albertslund municipalities), technology providers (Cisco, TDC), and research institutions. The DOLL Living Lab served as a neutral testing ground where multiple vendors could demonstrate solutions side-by-side, enabling informed procurement decisions.[11]

Results

Copenhagen's digital twin implementation delivered measurable improvements across multiple operational and environmental dimensions, though comprehensive quantified results specific to waste management within the integrated platform remain limited in available documentation.

- **Operational Improvements**: The integrated platform enabled real-time monitoring and control of city infrastructure across the seven-mile test area. City operators gained access to granular data on lighting performance, parking utilization, air quality conditions, and waste bin fill levels through a unified dashboard interface. The system successfully demonstrated the technical feasibility of converging multiple urban systems onto a single digital platform.[12]
- **Waste Management Optimization**: While specific metrics for Copenhagen's integrated waste sensors are limited, the broader waste management improvements show significant potential. The city deployed sensors in approximately 600 waste bins in inner Copenhagen, enabling predictive collection planning and route optimization. Similar implementations using Nordsense technology in other cities achieved 80 per cent reduction in overflowing bins, 66 per cent decrease in street cleaning requests, and 64 per cent reduction in illegal dumping.[13]
- **Environmental Impact**: The platform contributed to Copenhagen's broader environmental goals, though specific CO_2 reductions from the digital twin are not separately quantified. Copenhagen successfully reduced overall CO_2 emissions by 80 per cent between 2009 and 2022, with waste management contributing to this achievement through the city's "Circular Copenhagen" plan targeting 59 000 tonnes of CO_2 reduction by 2024.[14]

(continued)

Case study: A digital twin including waste management in Copenhagen

Lessons learned

- **Integration Complexity Requires Strong Partnerships**: The success of Copenhagen's digital twin relied heavily on close collaboration between municipal government, technology vendors, and telecommunications providers. The partnership between Copenhagen, Cisco, and TDC demonstrated that complex smart city initiatives require sustained commitment from multiple stakeholders with clear roles and responsibilities.
- **Interoperability as a Foundation**: Converging lighting, parking, air quality, and waste management systems onto the same API and data platform significantly reduced lifecycle costs and simplified cybersecurity management. The integrated approach enabled cross-system analytics that would not be possible with siloed implementations, though it required substantial upfront investment in platform architecture and data standardization.
- **Pilot Scale Enables Learning**: The seven-mile test area provided sufficient scale to validate technologies while remaining manageable for implementation and troubleshooting. This approach allowed the city to test and refine solutions before broader deployment, reducing risks associated with city-wide rollouts.
- **Data Quality and Sensor Maintenance**: Maintaining sensor functionality and data quality across diverse urban environments requires ongoing attention. The success of waste management optimization depends on reliable sensor performance, regular calibration, and robust data governance frameworks.
- **Scalability Considerations**: While the pilot demonstrated technical feasibility, scaling to broader urban areas requires significant infrastructure investment and organizational change management. The platform architecture developed for DOLL has informed expansion to other Copenhagen neighbourhoods, but full city-wide implementation remains a multiyear endeavour.

Conclusion

Copenhagen's digital twin initiative, centred around waste management and integrated urban systems monitoring, demonstrates the transformative potential of converging IoT sensors, data analytics, and cloud-based platforms for urban management. The project successfully established a technical foundation for data-driven city operations while contributing to Copenhagen's ambitious climate goals.

The initiative's strength lies in its integrated approach, combining multiple urban systems (waste, lighting, parking, air quality) into a unified digital platform rather than implementing isolated solutions. This convergence enabled cross-system optimization and provided city operators with comprehensive situational awareness that would not be possible through separate systems.

However, the project also illustrates the complexity of large-scale urban digitization. Success required sustained partnerships between government, technology providers and telecommunications companies, along with significant upfront investment in platform architecture and sensor infrastructure. The transition from traditional scheduled operations to data-driven, demand-based services represents a fundamental shift in municipal operations that extends beyond technology to encompass workforce training, process redesign, and organizational change management.

For cities considering similar digital twin implementations, Copenhagen's experience demonstrates the importance of starting with pilot-scale deployments, ensuring strong stakeholder partnerships, and maintaining focus on measurable outcomes that support broader urban sustainability goals. The project confirms that digital twins can serve as powerful tools for urban innovation when implemented with appropriate technical architecture, stakeholder engagement, and alignment with city-wide strategic objectives.

Use case 2: XR-enabled fieldworkers (Horizon 1)

Description

Extended reality (XR) technologies such as augmented reality (AR) and virtual reality (VR), can significantly enhance the capabilities of government fieldworkers such as building inspectors and environmental inspectors. By leveraging XR, fieldworkers can receive real-time, remote guidance from experts who are virtually present through digital twins and live data feeds. For example, XR headsets or smart glasses can overlay crucial information such as schematics, troubleshooting tips, or safety instructions, directly onto the fieldworker's view, enabling hands-free, efficient task completion. Additionally, VR simulations can be used to train fieldworkers in realistic, immersive environments, allowing them to practice high-risk tasks without the dangers of real-world scenarios. By integrating AI, fieldworkers can receive data-driven insights and recommendations in real-time, streamlining workflow and improving safety and productivity.

Impacts

1) **Efficiency**: With the use of XR glasses in the field, workers are able to find existing documents on items such as water pumps, valves, and so on, which give detailed explanations on how to repair or replace these times, and can include instructional videos, which traditionally would require the field worker to review at their desk and then go to the field for the repair or replacement. These types of services can reduce repair and replacement times significantly, by reducing travel time and office time.
2) **Quality of life**: The field workers and residents can see an increased quality of life improvement through the use of this technology, as field workers spend less time travelling between office and field, and residents get services back online sooner. Driving is one of the most stressful and dangerous tasks we undertake daily, so removing even the slightest amount of driving time helps reduce stress for workers.
3) **Enhanced services**: Through the use of XR municipalities are able to bring on less skilled workers and train them with hands on field training with repair and replacement manuals that they can see while performing the actual work, as well as video training that meets the needs of varying learning types. This knowledge being readily available in the field will enhance the services municipalities can provide to their residents by ensuring quicker response times and repairs to critical infrastructure.
4) **Increased uptime**: The availability of information at the fingertips of field workers when encountering new or unexpected challenges in the field, will help speed up repairs thus increasing the uptime of critical infrastructure. These new tools bring in proper maintenance documents to ensure field workers are performing all necessary maintenance tasks to keep infrastructure operating efficiently and extending its life of operation.
5) **Knowledge sharing**: The ability to transfer data from experienced staff to new staff has been a challenge for municipalities for decades. Through XR technology you can virtually bring in a more senior staff member to assist other staff members when they are performing services across cities in all areas of operations.

Key beneficiaries

- City management
- Field workers
- Residents
- Utilities
- Record management

Key technologies

- **Digital twins**: The infrastructure and the documents and videos that go along with the infrastructure can be stored and accessed within a digital twin, ensuring all users have access to its precise location and any related information at any location.
- **AR/VR**: For this technology to be effective cities will need the requisite equipment such as AR gasses and systems to operate the AR/VR glasses, to ensure all field workers can access relevant data.
- **IoT**: With the incorporation of IoT devices within critical infrastructure field workers can receive real-time updates on the infrastructures operating conditions.

SDG alignment

- **SDG 4: Target 4.4** By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship
- **SDG 16: Target 16.6** Develop effective, accountable and transparent institutions at all levels

Risk level

Table 2 Risk level: XR-enabled fieldworkers

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	The use case presents a low impact on public safety. However, it can improve the outcomes for public safety due to lower disruption of infrastructure.
Stakeholder acceptance	Low	Medium	High	This use case will have newer training methods, which may reduce acceptance rates at first. Through training and champions, the technology has the potential to have a high acceptance.
Data privacy and security	Low	Medium	High	With the data being stored locally and consists of commonly found documents, and the AR glasses not connecting to a network, reduce the data privacy risks.
Financial/ operational	Low	Medium	High	With all new technologies, costs are still higher than more commonly available technologies on the market. However, adoption is growing which will reduce costs.

Implemented in:

Vienna, Austria; Coral Gables, USA; Chandler, USA

Case study: Vienna AR-enabled building permitting

Context

Vienna receives more than 13 000 building applications each year, yet its legacy paper-based workflow meant an average processing time of twelve months per permit. Some 200 tonnes of archived drawings and fragmented rulesets made verification labour-intensive for the municipal building regulators and opaque for citizens. To handle rapid population growth (+21 000 residents annually between 2012–2021) the city launched the research-and-development project BRISE Vienna (Building Regulations Information for Submission Envolvement). Backed by EUR 4.8 million from the EU's Urban Innovative Actions programme, BRISE set out to create a fully digital, end-to-end permit "pipeline" that combines building information modelling (BIM), artificial intelligence (AI) and augmented reality (AR).[15]

Objective

BRISE pursues four strategic goals:

- Cut approval times by at least 50 per cent, reducing the typical cycle from 6–12 months to 3–6 months for standard residential projects.[16]
- Automate regulatory checking by comparing applicant BIM models against a city-generated 3D reference model that embeds all site-specific codes and zoning rules.[17]
- Increase transparency and citizen trust through AR visualisations that show neighbours the exact massing and shadow impact of planned buildings before construction.[18]
- Enable Building regulators work through AR visualisations to better understand the scope and impact of planned works.
- Future-proof municipal workflows and establish an open BIM data standard that can be re-used across other urban-planning services.[19]

Solution approach

- **OpenBIM submission plug-in**:The city distributes an IFC plug-in that lets architects export a rule-ready 3D "Building Application Model" directly from their native design software, avoiding new tools.
- **AI rule engine**: Machine-learning algorithms parse the submitted model, locate relevant clauses in the Vienna Building Code and flag non-compliances (e.g., escape-route length, parking minima).
- **3D Reference Model (REM)**: For every cadastral plot the system maintains a digital twin containing height limits, heritage zones and transport overlays, enabling instant clash detection between proposed and allowable volumes.
- **AR field module**: Inspectors and affected residents use tablets or HoloLens headsets to overlay approved volumes on the construction site, verifying compliance and improving public understanding.
- **Pilot governance**: Between June and December 2022, 13 planning offices submitted 17 real projects through the new pathway while MA 37 assigned an "all-hands" squad to fast-track reviews and document feedback.[20]

Results

- **Time savings**: Digital submissions reached decision stage in 3–4 months, versus ~8 months for comparable analogue files, confirming the 50 per cent acceleration target.
- **Pilot uptake**: Positive feedback from the 13 pilot teams prompted a further 13 firms to enrol, signalling broader acceptance.
- **Scalability potential**: Internal assessments project annual savings of 50 000 staff hours and EUR 7 million once all 13 000 yearly applications use the system.

(continued)

Case study: Vienna AR-enabled building permitting

Lessons learned

- **Voluntary pilots lower resistance**: Allowing early adopters to opt in built trust and generated proof points before scaling city-wide. The intentional use of a voluntary, incremental approach to reduce resistance and offer real-world proof of concept.
- **Seamless toolchain is critical**: Embedding export capability in mainstream BIM software avoided costly retraining and was cited by architects as a key adoption driver.
- **Legal robustness**: Every AI flag links to a clause citation so inspectors can audit decisions; this slowed development but secured regulator confidence.
- **Role evolution**: Automated checks turned inspectors and designers into collaborators rather than adversaries, improving model quality before formal submission.
- **Skills investment**: MA 37 created new roles (BIM officer, AR inspector) and mandatory upskilling programmes to embed digital competencies across the authority

Conclusion

BRISE Vienna shows how BIM, AI and AR can converge into a single digital-twin workflow that halves permit times, cuts errors and demystifies planning decisions for citizens. By digitising submissions, automating rule checks and overlaying approvals on-site via AR, Vienna has transformed a year-long bureaucratic hurdle into a transparent, data-driven service. The project underscores the value of open standards, incremental piloting and continuous stakeholder engagement. As the city moves towards full roll-out, BRISE offers a replicable blueprint for jurisdictions worldwide seeking to modernise building regulation while boosting housing delivery and public trust.

Use case 3: Next generation 311 Services (Horizon 3)

Description

311 services create avenues for citizens to engage with the city administration and report issues with local services and infrastructure. Virtual world technologies can create next generation 311 services for citizens. Digital twins can create virtual replicas of urban environments that are updated with real-time data from sensors, service requests, and citizen inputs to visualize the status of ongoing infrastructure repairs or quality-of-life improvements, allowing residents to track requests. MR can enable residents to use their smartphones or AR glasses to scan their surroundings and access information about service requests, maintenance schedules, or the progress of repairs.

Impacts

1) **Quality of life**: Enhanced 311 services significantly improve urban quality of life by providing citizens with instant, 24/7 access to city services and real-time updates on issue resolution.
2) **Service improvement**: AI-powered chatbots and automated workflow routing reduce average response times from hours to minutes while improving service accuracy through intelligent categorization. Digital twins provide city departments with comprehensive data visualization tools that enable predictive maintenance and resource optimization.
3) **Citizen engagement**: Next generation 311 platforms transform passive complaint systems into active civic participation tools. MR can enable residents to use their smartphones or AR glasses to scan their surroundings and access information about service requests, maintenance schedules, or the progress of repairs.

Key beneficiaries

- Citizens and residents
- City department staff (e.g., planning, waste management, street transportation, public works)
- Community organizations
- Local government officials

Key technologies

- **Digital twin**: Creates real-time virtual replicas of urban infrastructure that integrate citizen service requests with sensor data, enabling predictive maintenance and comprehensive status tracking of ongoing repairs and improvements across the city.
- **AR**: Enables citizens to point their smartphones at infrastructure problems to automatically identify issues, access repair histories, and visualize scheduled improvements overlaid on the physical environment.
- **GenAI**: Powers intelligent chatbots that understand natural language service requests, automatically categorize issues, generate work orders, and provide personalized updates while learning from interaction patterns to improve service delivery.
- **IoT**: Connects city infrastructure sensors with 311 systems to enable proactive issue detection, automatic service request generation, and real-time status updates that keep citizens informed of repair progress and completion.

SDG alignment

- **SDG 11: Target 11.3** Enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries.
- **SDG 16: Target 16.6** Develop effective, accountable and transparent institutions at all levels.

Risk level

Table 3 Risk level: Next generation 311 Services

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	This use case enhances public safety by enabling faster non-emergency response coordination (e.g., addressing potholes and waste accumulation) and proactive infrastructure monitoring, with minimal direct safety risks.
Stakeholder acceptance	Low	Medium	High	While citizens generally welcome improved services, some citizens may resist process/service changes. Many users will also be unfamiliar with MR technologies and require upskilling and public engagement to encourage adoption.
Data privacy and security	Low	Medium	High	Service requests contain location and personal data requiring robust protection. Integration with IoT sensors expands potential attack surfaces needing security measures.
Financial/ operational	Low	Medium	High	This solution requires up-front cost of creation of the front end and backend system but also ongoing maintenance of the solution and new workstreams to process a new channel of citizen engagement.

Implemented in:

N/A

Case study

For this use-case, no relevant case study has been identified due to the horizon 3 level.

Use case 4: Citizen sentiment mapping (Horizon 2)

Description

AI-enabled citiverse technologies, including AI and digital twins, can be used to capture and analyse citizen sentiment, allowing governments to make informed decisions based on public opinion. By using virtual replicas of city spaces and leveraging data from social media, surveys, and sensors, authorities can visualize citizen sentiment across different neighbourhoods. AI algorithms can process these data to detect patterns, trends, and emerging concerns, which can then be displayed on dynamic models of the city. This interactive system enables policymakers to track public sentiment on a variety of issues and engage citizens in the decision-making process by visualizing how their feedback impacts policy.

Impacts

1) **Resource allocation**: Leveraging real-time sentiment data enables city authorities to prioritize resource deployment to neighbourhoods or issues exhibiting increased concern or dissatisfaction, ensuring that service delivery is responsive and targeted to emerging community needs.
2) **Quality of life**: Visualizing sentiment trends helps identify areas facing social stress, discontent, or unmet needs. This allows for targeted interventions, enhancing residents' well-being, satisfaction, and perceptions of their local environment.
3) **Effective policy making**: Integrating aggregated sentiment analysis enables evidence-based decision making that reflects actual community preferences and emerging priorities, improving the effectiveness, responsiveness, and legitimacy of public policies.
4) **City service improvement**: The feedback loop generated by sentiment mapping guides continuous improvement in municipal services. By highlighting strengths and weaknesses as perceived by citizens, it enables adaptation and refinement to better meet local expectations.
5) **Citizen engagement**: Interactive visualizations empower residents to see how their feedback influences city actions and policies, fostering transparency, mutual trust, and active participation in local governance. This strengthens democratic engagement and creates a more collaborative relationship between citizens and government.

Key beneficiaries

- Citizens and residents
- Local government officials
- City department staff
- Community organizations
- Researchers and academic institutions

Key technologies

- **Digital twin**: Enables real-time virtual replicas of city spaces dynamically updated with sentiment data and urban analytics.
- **AR & VR**: Immersive visualization platforms enabling policymakers and citizens to explore sentiment data spatially and contextually.
- **AI**: AI Algorithms can be leveraged for natural language processing, sentiment analysis, trend detection, and predictive modelling.
- **GenAI**: Can enable Advanced conversational agents to interact with citizens, gather nuanced feedback, and generate multilingual reports.
- **IoT**: **Sensor** networks capturing environmental and mobility data can complement sentiment inputs for holistic urban monitoring.

SDG alignment

- **SDG 11: Target 11.3** Enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries.
- **SDG 16: Target 16.7** Ensure responsive, inclusive, participatory and representative decision making at all levels.

Risk level

Table 4 Risk level: Citizen sentiment mapping

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	Can improve public safety through early detection of social dissatisfaction hotspots.
Stakeholder acceptance	Low	Medium	High	May face resistance due to privacy concerns from some community members.
Data privacy and security	Low	Medium	High	Social media data requires stringent anonymization, security protocols and ethical usage.
Financial/ operational	Low	Medium	High	This solution requires up-front cost of creation of the front end and backend system but also ongoing maintenance of the solution.

Implemented in:

Helsinki, Finland; New York, USA: Barcelona, Spain; Singapore; London, UK; Dublin, Republic of Ireland; Tallinn, Finland; Aachen; Germany Leicester, UK

Case study: Citizen sentiment mapping and engagement platform in Patras, Greece

Context

The city of Patras, Greece's third-largest urban centre and regional capital of Western Greece, has emerged as a pioneering example of integrating citizen sentiment mapping into urban governance through digital twin technology.

With approximately 214 000 inhabitants, Patras confronts the typical challenges of medium-sized European cities, including aging infrastructure, environmental monitoring, traffic management, and the critical need for meaningful citizen participation in decision-making processes. In 2020, building upon earlier smart city initiatives launched through the EU Intelligent Cities Challenge, the Municipality of Patras embarked on developing an Urban Resilience Digital Twin that fundamentally transforms how public sentiment is captured, analysed, and integrated into urban planning and service delivery. This initiative represents a significant evolution from conventional approaches to service delivery and planning by creating a dynamic, AI-powered digital replica that continuously learns from citizen interactions, while providing real-time insights into community needs and priorities.

The project emerged from recognition that effective urban resilience requires not only technical infrastructure monitoring but also deep understanding of citizen experiences, concerns, and satisfaction levels across different neighbourhoods and demographic groups. Traditional methods of citizen engagement through surveys, town halls, and complaint systems often resulted in fragmented, delayed feedback that failed to inform timely decision making or capture emerging trends before they became critical issues.[21]

Objective

The Patras Urban Resilience Digital Twin aimed to transform urban governance by establishing a comprehensive, AI-driven platform that continuously captures, analyses and visualizes citizen sentiment to enable data-driven decision making and enhance urban resilience. The primary objective was to create a dynamic system that transforms fragmented citizen feedback into actionable intelligence for municipal authorities, enabling proactive rather than reactive urban management.

The digital twin seeks to address multiple interconnected challenges: improving the speed and quality of municipal response to citizen concerns, identifying emerging problems before they escalate, understanding spatial patterns of satisfaction and dissatisfaction across the city, and creating transparent feedback loops that demonstrate to citizens how their input directly influences policy and service delivery decisions. By integrating real-time sentiment analysis with predictive modelling, the system aims to enhance the efficiency of municipal operations and the level of citizen trust in local government.

A key innovation of the Patras approach is its focus on neighbourhood-level granularity, enabling city managers to understand how different areas experience urban services and identifying localized issues that might be overlooked in city-wide assessments. The system is designed to support evidence-based urban planning that reflects actual citizen priorities rather than assumptions about community needs, ultimately contributing to more inclusive and effective governance that enhances overall urban resilience and quality of life.

Solution approach

The solution approach implemented in Patras leverages the Sense. City platform, a versatile citizen-sourcing digital tool developed and supported by the University of Patras. Sense. City enables direct communication between citizens and municipal services by allowing residents to report urban issues in real time through an intuitive mobile and web application. The platform captures geo-located data on a wide range of urban problems, including infrastructure defects such as broken streetlights, damaged traffic signals, abandoned vehicles, and general environmental concerns. User reports optionally include photos and are categorized for streamlined issue management. These data are combined with information from social media.

(continued)

Case study: Citizen sentiment mapping and engagement platform in Patras, Greece

Citizens have access to a public portal where they can monitor reported issues, track the progress of their resolution, and assess the performance of various city departments. Municipal authorities use analytics dashboards showcasing trends in reported problems, response times, and resolution rates.

To process and analyse citizen input in Patras, the platform integrates functionalities such as GPS, accelerometer, camera and microphone features inherent in modern smartphones, effectively transforming residents into living sensors within the urban environment. The system's back-end manages data related to geofencing and critical infrastructure points, offering municipality officials a robust overview of urban challenges. The platform is open-source nature, enabling adaptation and deployment in different cities worldwide and includes an open API that allows interoperability with other urban management systems.

Lessons learned

The experiences from Patras and comparable urban resilience digital twin projects offer several key insights for cities aiming to use citizen-driven digital governance and AI-powered platforms:

- **Community engagement as a cornerstone**: Strong citizen participation is essential citizens are not just data providers but play the pivotal roles of co-creators and end users. Platforms like Sense. City, by enabling real-time problem reporting and feedback, showed that cities must treat residents as "sensors" and collaborators, not merely service recipients. Transparency in how issues are handled and visible impact on service quality significantly boosts trust and participation.
- **Technical and data integration challenges**: Successful operation of urban digital twins depends on integrating diverse and sometimes incompatible data sources (sensors, user reports, municipal datasets) into a unified analytics and management platform. Achieving true interoperability remains a persistent challenge requiring standardized APIs, open data policies, and collaborative governance. Careful mapping of infrastructure and organizational processes is needed for scaling beyond pilot implementations.
- **Prioritizing data privacy and ethical use**: Handling location-based, time-stamped, and personally triggered data for urban resilience management requires robust frameworks for data privacy, security, and ethics. Open platforms need built-in mechanisms for anonymization and clear policies for how and why data are collected, processed, and shared – a non-negotiable to sustain public trust.
- **Organizational and capability building**: Ensuring the successful development and long-term sustainability of digital twins demands upskilling not only for digital specialists within municipalities but also among administration staff and related stakeholders. Investments in ongoing training, interdisciplinary collaboration (across academic, civic and business domains), and cross-sector knowledge sharing are critical to adapt to evolving requirements and technological advances.
- **Continuous feedback and adaptive planning**: There is value in incorporating live user feedback and dynamic analytics into city management. Real-time citizen sentiment data, paired with analytics dashboards, improve the ability of cities to spot trends and adapt from reactive problem handling to proactive urban governance.
- **Planning for scalability and sustainability**: Many digital city projects face obstacles in transitioning from pilot to production scale due to challenges in funding, limited municipal resources, and the need for strong collaborative networks. Sustainability planning – including guaranteed operational funds, governance models, and alignment with policy frameworks – is vital for these projects to deliver long-term urban resilience benefits rather than short-lived experimentation.

(continued)

Case study: Citizen sentiment mapping and engagement platform in Patras, Greece

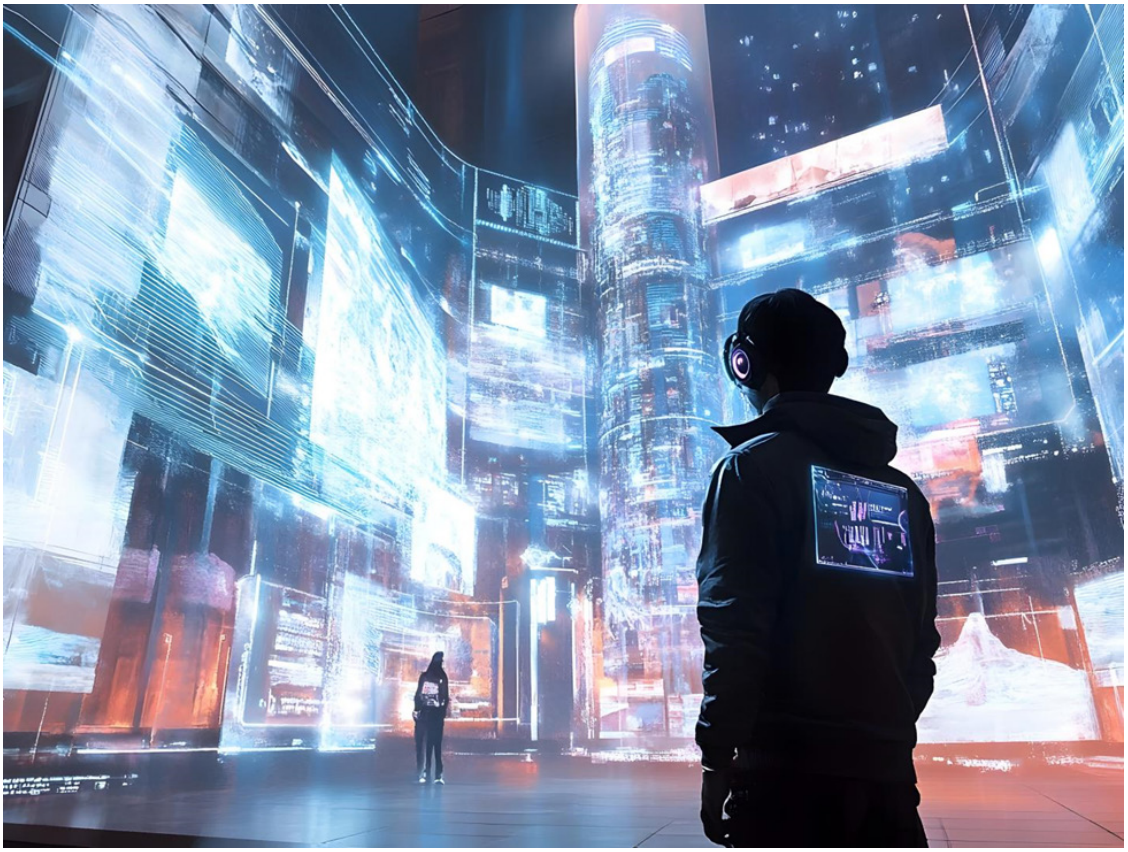
Conclusion

The integration of real-time citizen feedback with predictive analytics creates powerful capabilities for proactive urban management that addresses problems before they escalate into broader system failures. By providing neighbourhood-level granularity in sentiment analysis, the system enables targeted interventions that optimize resource allocation, while building stronger connections between citizens and local government. The transparent feedback mechanisms demonstrate to citizens how their input directly influences policy and service delivery, creating positive reinforcement cycles that encourage continued civic engagement.

Use case 5: Virtual town halls (Horizon 2)

Description

Virtual town halls, powered by the metaverse and XR technologies, offer an innovative way for citizens to engage with local government and community leaders. These virtual events create immersive, 3D environments where citizens can participate in open forums, ask questions, and provide feedback in real time, no matter their physical location. Using avatars and virtual spaces, participants can attend sessions with a level of presence and interaction that traditional video conferencing tools cannot match. Additionally, AI-powered moderators can assist in managing questions, prioritizing issues, and ensuring a smooth flow of conversation.



Impacts

1) **Increased accessibility and inclusion**: Virtual town halls remove geographical and physical barriers, enabling broader participation from citizens, including those with limited mobility or from remote areas.
2) **More effective communication**: The interactive and immersive environment promotes more open and productive dialogue between citizens and municipal representatives.
3) **Cost reduction**: Virtual meetings can lower the costs associated with organizing physical events such as venue rental or travel expenses.
4) **Environmental benefits**: Reduced need for travel contributes to lower carbon emissions.
5) **Enhanced citizen engagement**: Virtual platforms foster a more engaging and participatory experience, encouraging citizens to take a more active role in civic life.
6) **Improved quality of life**: By offering convenient and inclusive access to civic processes, virtual town halls contribute to more responsive governance and citizen satisfaction.

Key beneficiaries

- Citizens
- Local governments
- Community organizations
- Individuals with mobility limitations

Key technologies

- **Metaverse**: Serves as the core platform for hosting persistent and immersive virtual environments. Citizens can engage with public officials in real-time, using personalized avatars within interactive 3D spaces.
- **VR**: Enables a fully immersive experience that simulates the feeling of being physically present in a town hall meeting. VR enhances focus, engagement, and the emotional connection between citizens and public dialogue.
- **AI**: Powers intelligent assistants and moderators that manage questions, facilitate discussions, and analyse citizen feedback in real time, ensuring a smooth and inclusive participatory process.
- **GenAI**: Assists in automatically generating content such as meeting summaries, visual materials, interactive simulations, and responses to frequently asked questions, improving efficiency and accessibility.

SDG alignment

- **SDG 11: Target 11.3** Enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries.
- **SDG 16: Target 16.7** Ensure responsive, inclusive, participatory and representative decision making at all levels.

Risk level

Table 5 Risk level: Virtual town halls

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	Virtual environments can minimize physical safety risks associated with in-person gatherings. However, there are unique public safety risks in virtual environments such as fraud and impersonation and online abuse.
Stakeholder acceptance	Low	Medium	High	Participation and adoption may be influenced by digital literacy and access to necessary devices.
Data privacy and security	Low	Medium	High	Collection and storage of personal data (e.g., for identity verification and access) requires robust safeguards to prevent data breaches and unauthorized access.
Financial/ operational	Low	Medium	High	Initial investments in technology and training may be significant but could be offset by long-term savings from reduced physical events.

Implemented in:

Seoul, Republic of Korea

Case study: Seoul's Metaverse Seoul Platform

Context

In response to the growing trend of digital transformation and the need for innovative public service delivery methods, the Seoul Metropolitan Government recognized the potential of the metaverse to enhance citizen engagement and streamline administrative processes. The COVID-19 pandemic further underscored the necessity for contactless communication channels between the government and its citizens. These factors motivated Seoul to explore and implement a virtual platform that could bridge the gap between the city administration and its residents.

The "Metaverse Seoul" project is the world's first public metaverse platform implemented by a city government, designed to enhance accessibility, citizen participation, and digital public service delivery. Through immersive virtual environments, citizens can attend town hall meetings, consult with officials, and access various services – all without physical constraints. The platform exemplifies how emerging technologies like XR, AI, and the metaverse can foster inclusive, participatory urban governance and set a global benchmark for smart city innovation.[22]

(continued)

Case study: Seoul's Metaverse Seoul Platform

Objective

The primary goal of Metaverse Seoul was to create an inclusive, accessible, and interactive virtual environment that transcends physical limitations, enabling citizens to:

- Engage in real-time dialogues and consultations with city officials.
- Participate in cultural, educational, and economic activities virtually.
- Contribute actively to urban policymaking through open, collaborative, and immersive platforms.

This effort sought to foster deeper citizen involvement and broaden access to government services, enhancing democratic participation and administrative transparency.

Solution approach

The implementation of Metaverse Seoul was structured into a multiphase plan.

Development of the metaverse platform: The SMG developed a comprehensive metaverse platform, integrating various public services and virtual spaces. This platform was designed to be accessible via smartphones, ensuring wide reach among citizens.

Virtual Representation of city facilities: Key city facilities, including the Seoul City Hall and the mayor's office, were recreated in the virtual environment. Citizens could create avatars to navigate these spaces, interact with officials, and access information.

1) **Diverse service offerings**: Metaverse Seoul provided a range of services such as:
    - **Administrative services**: Citizens could handle civil complaints, consult with public officials, and access various administrative documents.
    - **Economic support**: Virtual spaces like the Fintech Lab and Business Support Center offered resources for entrepreneurs and businesses, including remote consulting sessions and promotional opportunities.
    - **Educational and cultural activities**: The platform hosted virtual campuses, tourist attractions, and seasonal events, providing educational content and cultural experiences.
2) **Citizen participation features**: Tools were integrated to encourage citizen involvement in governance such as feedback mechanisms and participatory events.
3) **Security and ethical guidelines**: To ensure a safe and respectful environment, the SMG implemented ethical guidelines and security measures, addressing concerns like data privacy and appropriate conduct within the metaverse.[23]

Results

The launch of Metaverse Seoul yielded several positive outcomes:

- **Increased accessibility**: Citizens could access public services and participate in civic activities without geographical or physical limitations, promoting inclusivity.
- **Enhanced citizen engagement**: The interactive nature of the platform fostered greater involvement from residents in city governance and community events.
- **Innovation in public service delivery**: Seoul set a precedent as the first city to implement a public metaverse platform, showcasing a novel approach to digital governance.
- **Global recognition**: Metaverse Seoul attracted attention from international organizations and media, highlighting Seoul's leadership in integrating technology with public administration.[24]

(continued)

Case study: Seoul's Metaverse Seoul Platform

Lessons learned

The implementation of Metaverse Seoul provided valuable insights:

- **Importance of user accessibility**: Ensuring the platform is user-friendly and accessible across various devices is crucial for widespread adoption.
- **Need for robust security measures**: Addressing data privacy and establishing ethical guidelines are essential to maintain user trust and platform integrity.
- **Continuous engagement and feedback**: Regularly soliciting user feedback helps in refining services and addressing emerging needs effectively.
- **Scalability considerations**: Planning for future expansions and technological advancements ensures the platform remains relevant and capable of integrating new services.

Conclusion

Seoul's Metaverse Seoul initiative exemplifies how metaverse technology can be effectively utilized to enhance public service delivery and citizen engagement. By creating an immersive and interactive virtual environment, the Seoul Metropolitan Government has paved the way for innovative digital governance, setting a benchmark for other cities to follow. The success of this initiative underscores the potential of virtual platforms in creating more connected, inclusive, and participatory urban communities.

Use case 6: Civil servant onboarding and training (Horizon 2)

Description

By creating immersive training environments, new employees can interact with digital replicas of government buildings, familiarizing themselves with workplace dynamics, policies, and procedures in a safe, virtual setting. In a metaverse-like environment, new recruits can simulate real-world scenarios such as handling public inquiries, managing emergencies, or collaborating with colleagues across departments. AI-powered virtual assistants can guide employees through their training, providing tailored learning paths and assessments. This would not only accelerate the onboarding process but also improve knowledge retention, employee engagement, and overall job preparedness, helping civil servants transition into their roles more effectively.

Impacts

1) **Enhanced learning experience**: Immersive environments provide hands-on experience, allowing employees to practice skills in realistic scenarios without real-world consequences.
2) **Increased engagement**: Interactive and gamified elements can make training more engaging, leading to higher completion rates and better retention of information.
3) **Cost efficiency**: Virtual training reduces the need for physical resources, travel, and venue costs associated with traditional training methods.
4) **Standardized training**: Ensures all employees receive consistent training content, maintaining uniformity in understanding policies and procedures.
5) **Safe environment for mistake-making**: Allows trainees to learn from errors in a controlled setting, building confidence before facing real-world situations.

Key beneficiaries

- New employees
- HR & training departments
- Government agencies

Key technologies

- **Metaverse platforms**: Provide immersive virtual environments replicating real-world government settings for training purposes.
- **VR**: Offers fully immersive experiences, allowing trainees to interact with 3D simulations of their workplace.
- **GenAI**: Powers virtual assistants that guide trainees through personalized learning paths and assessments.
- **Digital twins**: Create accurate digital replicas of physical government buildings and environments for realistic training scenarios.

SDG alignment

- **SDG 4: 4.4** By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship.
- **SDG 8: 8.2** Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors.

Risk level

Table 6 Risk level: Civil servant onboarding and training

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	Training occurs in a virtual environment, eliminating physical safety risks typically associated with in-person training or site visits.
Stakeholder acceptance	Low	Medium	High	Participation and adoption may be influenced by digital literacy and access to necessary devices.
Data privacy and security	Low	Medium	High	Sensitive information such as personnel records or simulated scenarios involving citizens, requires robust data protection and cybersecurity.
Financial/ operational	Low	Medium	High	Upfront investments in hardware, content development, and training may be significant, though long-term operational savings are expected.

Implemented in:

San Diego County, USA; Sharjah, UAE; Dubai, UAE

Case study: Immersive virtual training in San Diego

Context

Government agencies face significant challenges in effectively onboarding and training new civil servants, particularly those in high-stakes roles such as caseworkers who make critical decisions affecting vulnerable families. Traditional training methods are often time consuming, resource intensive, and may not adequately prepare employees for the complex real-world scenarios they will encounter. In San Diego County, officials recognized that new caseworkers needed more practical experience to help them conduct eligibility interviews and make accurate benefit determinations – decisions that directly impact families' access to food, health care and housing assistance.

The County identified that error rates in eligibility decisions were problematic, with new caseworkers lacking sufficient "real world" experience to confidently navigate challenging client interactions. Traditional shadowing programmes, while valuable, were inconsistent due to high turnover rates and overworked senior staff, leaving some trainees inadequately prepared for their critical responsibilities. With the understanding that effective caseworker training required innovative approaches, San Diego County partnered with Accenture to explore how immersive technologies could transform civil service preparation.[25]

Objective

The primary objectives of San Diego County's VR training initiative were to:

- Develop an immersive training programme providing new caseworkers with realistic scenarios for practicing interview skills in a controlled environment.
- Reduce error rates in eligibility determinations by improving decision-making confidence and competency.
- Create standardized training experiences that could be consistently delivered regardless of senior staff availability.
- Accelerate the onboarding process while enhancing retention and job preparedness among new hires.[26]

Solution approach

San Diego County collaborated with Accenture to implement the Accenture Virtual Experience Solution (AVEnueS), a comprehensive VR training platform specifically designed for public sector applications. The implementation approach included several key components:

- **Development of realistic scenarios**: The team created highly authentic 360-degree VR simulations of typical caseworker-client interactions, featuring real actors filmed on green-screen technology and integrated into carefully designed virtual environments. Three primary scenarios were developed, each presenting different family crisis situations requiring nuanced assessment and decision making.
- **Interactive voice-based technology**: The platform utilized advanced voice recognition and natural language processing capabilities, allowing trainees to engage in realistic conversations within the simulation. Participants could choose from multiple questioning approaches for each topic, with each choice yielding different responses and information levels, closely mimicking real-world interview dynamics.
- **Experiential learning framework**: Trainees were placed in immersive situations where they conducted virtual eligibility interviews, assessed client needs, and made critical decisions about benefit eligibility. Following each VR session, participants engaged in facilitated reflection seminars to discuss their experiences, examine potential biases, and reinforce learning through collaborative analysis.
- **Accessible implementation**: The programme was designed for standalone VR headsets, eliminating the need for complex technical setups and making the training easily deployable across different locations and schedules. This accessibility ensured consistent training delivery regardless of logistical constraints.[27]

(continued)

Case study: Immersive virtual training in San Diego

Results

The implementation of San Diego County's VR training programme yielded significant positive outcomes across multiple dimensions:

- **Enhanced decision-making capabilities**: Trainees demonstrated markedly improved confidence in conducting eligibility interviews and making benefit determinations. The immersive nature of the training allowed participants to practice critical thinking and decision-making skills in realistic, high-pressure scenarios without real-world consequences.
- **Improved empathy and cultural competence**: Exposure to diverse, realistic client scenarios helped caseworkers develop deeper understanding of the complex situations faced by benefit applicants. This enhanced empathy translated into more compassionate and effective service delivery in actual client interactions.
- **Exceptional participant feedback**: Over 90 per cent of training participants reported that the VR experience significantly improved their engagement skills and provided valuable insight into their future role responsibilities. Participants praised the realism and effectiveness of the immersive training approach.
- **Industry recognition**: The programme received the prestigious "Best Use of Technology for Operations with an Internal Focus" award from the Information Technology Solutions Management for Human Services (ISM) affinity group, acknowledging its innovation and effectiveness in public- sector training.
- **Standardized training delivery**: The VR platform enabled consistent, high-quality training experiences regardless of senior staff availability, addressing a critical gap in traditional mentoring-based approaches.

Lessons learned

San Diego County's experience with VR-based caseworker training provided valuable insights for other government agencies considering similar implementations:

- **Authenticity drives engagement**: The use of real actors and carefully crafted scenarios proved crucial for creating believable, emotionally engaging training experiences that translated effectively to real-world application.
- **Technology acceptance requires user-friendly design**: Providing accessible, standalone VR equipment and intuitive interfaces was essential for successful adoption among staff members with varying levels of technological familiarity.
- **Reflective learning enhances impact**: The combination of immersive experience followed by facilitated group discussion created powerful learning opportunities, allowing participants to examine their decision-making processes and potential biases in a supportive environment.
- **Scalability enables broader impact**: The standardized, technology-enabled approach allowed for consistent training delivery across different locations and time periods, addressing traditional limitations of shadowing-based training programmes.

Conclusion

San Diego County's pioneering use of VR technology for caseworker training represents a transformative approach to public sector workforce development. By leveraging immersive technologies and AI-powered interactions, the programme successfully addressed critical challenges in traditional training methods while improving employee preparedness and service quality. The initiative's success demonstrates the significant potential for XR technologies to enhance civil service training, reduce operational costs, and ultimately improve outcomes for vulnerable populations served by government agencies. As digital tools become increasingly accessible and sophisticated, this model offers a scalable framework for modernizing public sector workforce development across diverse jurisdictions and service areas.[28]

Use case 7: Immersive library and community services (Horizon 3)

Description

The metaverse and XR can redefine the way library services are delivered by creating virtual libraries and community spaces. Libraries can build immersive spaces where users can explore different genres, attend author talks, or join book clubs in a fully interactive environment. Using XR technologies, users could also interact with digital versions of books, engaging with multimedia content such as videos, audio, or interactive exhibits. AI can be integrated to provide personalized recommendations and facilitate virtual librarians who can guide users through the resources. Libraries could also host virtual/XR educational sessions, making it easier for individuals to access workshops, research, and even remote study groups.

Impacts

1) **Quality education**: Virtual libraries can provide immersive learning environments where students explore subjects through interactive 3D models, virtual field trips, and collaborative study spaces that enhance comprehension and retention. Educational workshops and tutorials can be delivered through gamified experiences that make learning more engaging and accessible.
2) **Accessible education**: XR technology can eliminates geographical barriers, enabling users from remote locations to access world-class library resources, attend lectures by renowned experts, and participate in educational programmes regardless of physical limitations or distance. Multilingual support and assistive technologies can be integrated to serve diverse communities.
3) **Vocational education**: Libraries can offer virtual training programmes using immersive simulations for professional development, technical skills training, and career preparation in specialized fields such as health care, engineering, or digital media. Users can practice skills in lower-risk virtual environments.
4) **Community engagement**: Virtual spaces foster social connections through digital book clubs, community forums, cultural events, and collaborative projects that bring together individuals with shared interests from around the world. These platforms create new forms of civic participation and cultural exchange.
5) **Quality of life**: 24/7 access to library services, personalized learning experiences, and flexible engagement options could improve work-life balance, while providing intellectual

stimulation and social connection opportunities. Mental health benefits arise from reduced isolation and increased access to information and community support.

6) **Life-long learning**: Adaptive AI systems can create personalized learning pathways that evolve with users' interests and knowledge levels, supporting continuous education through micro-learning modules, skill assessments, and curated content recommendations. Users can pursue new subjects and interests at their own pace.

Key beneficiaries

- Students and researchers
- Educators and librarians
- Rural and remote communities
- People with disabilities
- Cultural heritage organizations

Key technologies

- **Digital twin**: Creation of virtual replicas of physical library spaces, enabling hybrid physical-digital experiences and preservation of architectural heritage.
- **Metaverse**: Immersive 3D virtual environments supporting social interaction, community building, and shared experiences across distributed users.
- **AR**: Augmented reality overlays that enhance physical books with multimedia content, provide navigation assistance, and create interactive storytelling experiences.
- **VR**: Fully immersive virtual experiences for educational content, virtual travel, historical recreation, and skills training in controlled environments.
- **GenAI**: Personalized content curation, automated metadata generation, virtual librarian assistants, and adaptive learning system optimization.
- **IoT**: Integration with smart library systems for inventory management, user analytics, environmental monitoring, and seamless digital-physical service coordination.

SDG alignment

- **SDG 4: Target 4.3** By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university.
- **SDG 4: Target 4.4** By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship.
- **SDG 4: Target 4.a** Build and upgrade education facilities that are child, disability and gender sensitive and provide safe, non-violent, inclusive and effective learning environments for all.
- **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.

Risk level

Table 7 Risk level: Immersive library and community services

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	Virtual library services present minimal direct physical risks, with primary interactions occurring in digital environments. However, consideration must be given to screen time limits, ergonomic concerns during extended XR use, as well as risks such as online abuse.
Stakeholder acceptance	Low	Medium	High	Implementation requires significant cultural change management as traditional library users may resist digital-first service models. Success depends on demonstrating clear value proposition, providing adequate training, and maintaining hybrid physical-digital options.
Data privacy and security	Low	Medium	High	Collection of detailed user behaviour data, reading preferences, learning patterns, and biometric information from XR devices creates significant privacy risks. Robust cybersecurity frameworks, transparent data governance, and compliance with international privacy regulations are essential.
Financial/ operational	Low	Medium	High	Substantial upfront investment required for XR hardware, software development, staff training, and ongoing maintenance. Long-term sustainability depends on demonstrated user adoption, cost-effective scaling strategies, and integration with existing library management systems.

Implemented in:

N/A

Case study

For this use-case, no relevant case study has been identified due to the horizon 3 level.

Use case 8: Interactive community support programmes (Horizon 2)

Description

Virtual world technologies, including metaverse platforms combined with AI-powered chatbots and immersive environments, can transform community support programmes by offering interactive, accessible platforms for residents to access help, guidance, and resources. These innovative systems create virtual spaces where local services can deliver real-time assistance for diverse community needs, including social services, mental health support and peer counselling. In virtual environments, individuals can participate in support groups, attend therapeutic workshops, and engage in meaningful discussions while maintaining privacy and

anonymity. The technology enables the creation of safe spaces where participants can share experiences, receive professional counselling, and develop coping strategies through immersive VR experiences designed to promote relaxation, stress reduction, and overall mental wellbeing. These platforms foster more connected, responsive, and inclusive community support systems by breaking down geographical barriers and reducing stigma associated with seeking help.

Impacts

1) **Enhanced mental wellbeing**: Immersive experiences can reduce stress and anxiety through guided relaxation and therapeutic simulations.
2) **Increased service accessibility**: Virtual platforms can provide 24/7 access to support services, overcoming geographic and scheduling barriers.
3) **Social inclusion**: Safe, anonymous environments foster peer support and community cohesion among diverse groups.
4) **Resource efficiency**: Digital delivery can lower operational costs and resource use compared to physical facilities.
5) **Skill development**: Participants can build coping strategies and digital literacy while engaging with virtual support tools.

Key beneficiaries

- Youth and adolescents
- Individuals with mental health challenges
- Elderly and isolated community members
- Families in crisis
- Healthcare workers and community service providers
- Marginalized communities
- Rural and remote residents

Key technologies

- **Metaverse**: Integrated virtual ecosystems providing persistent, shared environments where community members can access ongoing support services, participate in group activities, and build lasting connections.
- **AR**: Augmented reality applications that overlay support resources onto real-world environments, providing contextual assistance and guidance for community navigation and service access.
- **VR**: Fully immersive virtual environments designed for therapeutic interventions, relaxation experiences, and safe spaces for counselling and peer support activities.
- **MR**: Mixed reality systems combining virtual and physical elements to create hybrid support environments that enhance traditional community services with digital enhancements.
- **GenAI**: Generative AI systems creating personalized content, adaptive therapeutic experiences, and customized support resources based on individual user needs and preferences.
- **AI**: Artificial intelligence powering virtual assistants, chatbots, and automated support systems that provide 24/7 assistance, triage services, and personalized recommendations.

SDG alignment

- **SDG 3: Target 3.5** Strengthen the prevention and treatment of substance abuse, including narcotic drug abuse and harmful use of alcohol.
- **SDG 3: Target 3.7** By 2030, ensure universal access to sexual and reproductive health-care services, including for family planning, information and education, and the integration of reproductive health into national strategies and programmes.
- **SDG 3: Target 3.8** Achieve universal health coverage, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all.

Risk level

Table 8 Risk level: Interactive community support programmes

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	Virtual community support programmes pose moderate public safety risks related to potential misuse of platforms for harmful activities or inadequate crisis response mechanisms. However, proper moderation, professional oversight, and emergency protocols can mitigate these concerns while enhancing overall community safety through improved mental health support.

Table 8 Risk level: Interactive community support programmes (continued)

Risk attribute	Risk rating			Explanation
Stakeholder acceptance	Low	Medium	High	Implementation faces significant resistance from traditional service providers, community members unfamiliar with digital platforms, and those preferring face-to-face interactions. Success requires extensive community engagement, digital literacy training, and demonstrable benefits to overcome scepticism and build trust in virtual support systems.
Data privacy and security	Low	Medium	High	Collection and processing of sensitive personal, mental health, and behavioural data creates substantial privacy risks requiring robust cybersecurity measures, strict data governance protocols, and compliance with healthcare privacy regulations. Potential breaches could have severe consequences for vulnerable community members.
Financial/ operational	Low	Medium	High	Moderate implementation costs include technology infrastructure, staff training, ongoing platform maintenance, and professional oversight. However, potential cost savings from reduced physical infrastructure, improved wellbeing and mental health outcomes, and improved service efficiency can offset initial investments, making long-term sustainability achievable.

Implemented in:

Westminster, UK; Seoul, Republic of Korea; Manchester, UK

Case study: Westminster Council VR for Relaxation and Wellbeing Programme

Context

Westminster Council, serving one of London's most diverse and complex urban environments, faced significant challenges in supporting communities affected by serious youth violence. Traditional community outreach programmes struggled to engage with hard-to-reach demographics. The area's high rates of youth violence, combined with limited trust between residents and local authorities, created barriers to effective community support delivery. Westminster's community engagement officers recognized that innovative approaches were needed to build meaningful connections and provide mental health support in a way that resonated with affected populations.[29]

Objective

The VR-RAW programme aimed to explore the transformative potential of virtual reality technology as a tool to foster relaxation and wellbeing within inner-London communities impacted by serious youth violence. Specific objectives included: utilizing VR technology to promote wellbeing, community cohesion, and support among diverse groups; providing innovative tools for stress management and emotional regulation; creating safe, engaging environments for community members to access mental health resources; and evaluating the effectiveness of immersive technology in breaking down barriers to traditional support services.

Solution approach

Westminster Council partnered with The FRED Company to implement a comprehensive three-year programme (2021-2023) spanning eight distinct projects, each running 6–12 weeks. The approach incorporated several key elements:

- **Immersive VR experiences**: Participants accessed carefully curated virtual environments designed for relaxation and stress reduction, including virtual nature scenes, mindfulness experiences, and calming interactive content. Sessions were delivered using professional VR headsets in neutral, accessible community spaces.
- **Community-led design**: Each project was co-created with target communities to ensure cultural sensitivity and relevance. The programme worked with diverse groups including young females aged 14–21, youth club members, and school pupils with special educational needs.
- **Flexible delivery model**: Services were provided through various settings including youth clubs, community centres, alternative educational provisions, and neutral spaces that felt safe and welcoming to participants.
- **Professional integration**: Qualified community engagement officers and VR project specialists worked collaboratively to deliver sessions, ensuring technical expertise and appropriate pastoral support were available.

(continued)

Case study: Westminster Council VR for Relaxation and Wellbeing Programme

Results

The VR-RAW programme achieved outcomes across multiple dimensions:

- **High engagement levels**: The programme successfully engaged 121 participants from diverse backgrounds, with particularly strong participation from groups that traditionally avoid council services. Participants demonstrated consistent attendance and active engagement throughout project cycles.
- **Mental health benefits**: Participants reported significant improvements in stress management, emotional regulation, and overall wellbeing. Qualitative feedback included statements such as: "I enjoy coming to our sessions because it puts my head away from all the stuff I usually think of on a day-to-day basis... Coming here releases some of the anger as the VR relaxes me".
- **Educational and employment outcomes**: Three participants were referred to employment support teams, one participant secured funding for a 12-week music programme and recorded professional tracks, and multiple participants showed improved school attendance and engagement.
- **Community integration**: Participants became more actively involved in broader community activities, with several receiving invitations to high-profile community events such as International Women's Day celebrations.
- **Service access improvements**: The programme significantly increased engagement with Westminster City Council services among previously hard-to-reach populations, creating pathways for ongoing support.[30]

Lessons learned

Key lessons learned that could be applied to other immersive community support programmes include:

- **Technology as an engagement tool**: VR proved highly effective at capturing attention and creating initial engagement, but success depended on combining technology with skilled human facilitators and meaningful follow-up activities.
- **Cultural sensitivity critical**: Projects that invested time in understanding and respecting community cultures, particularly working with culturally complex groups, achieved the strongest outcomes and sustained engagement.
- **Safe space creation**: Neutral, non-institutional venues were essential for building trust and encouraging participation among communities with historical mistrust of authority figures.
- **Holistic approach necessary**: The most successful interventions combined VR experiences with broader opportunities such as career exploration, creative expression, and community connections rather than treating VR as a standalone solution.
- **Professional training essential**: Staff required specialized training not only in VR technology operation but also in trauma-informed approaches and cultural competency to work effectively with vulnerable populations.[31]

Conclusion

Westminster's VR-RAW programme demonstrates the significant potential of immersive technology to transform community support delivery, particularly for hard-to-reach populations affected by social challenges. By combining innovative technology with community-centred design principles and professional expertise, the programme successfully broke down traditional barriers to service access, while achieving measurable improvements in participant wellbeing and community engagement. The initiative's success has led to the establishment of the Westminster VR Service, expanding the use of virtual reality technology across broader community support strategies. This case study illustrates how thoughtful implementation of emerging technologies can create new pathways for community connection, mental health support, and social cohesion in complex urban environments.[32]

Use case 9: Immersive city service delivery (Horizon 2)

Description

By creating virtual spaces and experiences that digitally recreate the real-world constituents will be freer to interact with government and their community members using technologies such as the metaverse, AR/MR/VR and blockchain to apply for and receive holistic services and benefits. Public services such as permit applications, benefit applications and non-emergency services can be administered through these environments. For certain populations, this may enable ease of access to government services. This medium can also enable public participation in decision making, including for proposed development plans.

Impacts

1) **Service accessibility**: Virtual access to government services regardless of location or mobility constraints can improve service accessibility.
2) **Quality of services**: Automated workflows, AI-driven personalization, and real-time feedback can improve efficiency and user experience.
3) **Citizen engagement**: Virtual town halls, interactive consultations, and gamified planning tools can boost public participation in decision making.
4) **Health and wellbeing**: Immersive services can reduce stress and waiting times and can support virtual assistance for health-related services and benefits, support community welfare.
5) **Economic development**: Streamlined permit and licensing processes can accelerate business startups and attract investment.

Key beneficiaries

- All residents, especially those with mobility or time constraints
- Urban planners and local councils conducting public consultations
- Senior citizens and people with disabilities
- Municipal employees benefiting from automated back-office support

- Startups and investors accessing business services

Key technologies

- **Metaverse**: Can host 3D city service environments mirroring physical offices and public spaces.
- **AR**: Can provide on-site or remote digital overlays at service kiosks, delivering contextual instructions and real-time queue updates.
- **VR**: Can enable immersive tutorials, virtual site inspections, and interactive training for complex procedures.
- **MR**: Can lends physical counters with holographic AI assistants to facilitate hybrid service delivery.
- **GenAI/AI**: Can automate document drafting, multilingual translations, and personalized service recommendations and power chatbots and virtual agents handling inquiries, triage, and data-driven process optimizations.
- **IoT**: Feeds live data on facility occupancy and environmental conditions into virtual interfaces for seamless physical-digital integration.

SDG alignment

- **SDG 11: Target 11.3** Enhance inclusive and sustainable urbanization and capacity for participatory planning and management.
- **SDG 16: Target 16.6** Develop effective, accountable and transparent institutions at all levels.

Risk level

Table 9 Risk level: Immersive city service delivery

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	Virtual channels may be exploited for misinformation or unauthorized access; robust verification and monitoring needed.
Stakeholder acceptance	Low	Medium	High	Resistance from officials and citizens accustomed to traditional in-person services; requires training and outreach.
Data privacy and security	Low	Medium	High	Handling sensitive personal and financial data demands stringent encryption, governance, and regulatory compliance.
Financial/ operational	Low	Medium	High	Significant initial investment and staff training required; long-term efficiencies justify costs.

Implemented in:

Seoul, Republic of Korea

Case study: Metaverse Seoul

Context

Seoul's municipal government serves approximately 10 million people across a complex urban landscape, requiring thousands of daily administrative transactions – from permit applications to social welfare enrolments. Physical service centres face capacity constraints, long waiting times, and accessibility barriers, particularly for senior citizens, people with disabilities, and shift workers. The COVID-19 pandemic further underscored the need for remote, resilient service delivery channels capable of maintaining continuity during lockdowns and public health crises. In response, Seoul launched Metaverse Seoul in November 2022, as the world's first government-developed metaverse platform, aiming to digitalize city hall, public consultations, and economic services within an immersive, 3D environment.[33]

Objective

Metaverse Seoul's primary objectives were to:

- Provide virtual access to core municipal services – including youth counselling, tax support, and document issuance – via a metaverse interface.
- Enhance citizen engagement through interactive town halls, virtual exhibit halls, and real-time feedback on development plans.
- Improve operational efficiency by leveraging AI chatbots for routine inquiries and blockchain for secure identity verification and document management.
- Stimulate local economic development by creating a metaverse startup district where businesses can showcase products and network with investors.[34]

Solution approach

Seoul Metropolitan Government partnered with leading tech firms to roll out a phased pilot for 3 200 users drawn from municipal employees, youth groups, and governance experts. Key elements included:

- **Virtual city halls & plaza**: 3D reconstructions of Seoul City Hall and Gwanghwamun Plaza recreated in the metaverse, enabling avatar-based navigation to service booths.
- **AI Chatbots & Seoul Wallet integration**: Natural-language assistants triage basic inquiries – such as benefit eligibility and application status – and integrate with the Seoul Wallet mobile app for seamless mobile-to-virtual transitions.
- **Youth counselling rooms**: Secure VR spaces where adolescents receive anonymous one-on-one mentoring via avatar, reducing stigma and increasing willingness to seek support.
- **Blockchain identity & documentation**: Distributed ledger technology underpins user authentication and issuance of digital certificates, minimizing fraud and streamlining record keeping.
- **Metaverse startup zone**: A dedicated district hosting virtual booths for fintech startups and SMEs to pitch to investors, attend workshops, and conduct product demos in real time.[35]

Results

- **Service uptake**: 85 per cent of pilot participants completed at least one municipal transaction (e.g., permit renewal, welfare application) within the metaverse platform.
- **Engagement**: Virtual town hall attendance doubled compared to physical events, with 78 per cent of attendees actively participating in live polls and Q&A sessions.
- **Operational efficiency**: AI chatbots handled 72 per cent of routine inquiries, reducing average human agent workload by 55 per cent.
- **Economic impact**: More than 150 virtual startup showcases attracted interest from 20 international investors, leading to preliminary funding discussions valued at approximately USD 2 million.
- **User satisfaction**: Pilot users rated their experience 4.6 out of 5, citing convenience and reduced waiting times as key benefits.

(continued)

Case study: Metaverse Seoul

Lessons learned

- **User onboarding**: Simplifying identity verification and onboarding increases user completion rates. The platform is tightly connected to a mobile app, enabling users to register by inputting personal details and uploading documents – such as ID cards, health insurance receipts, medical records, and other pertinent files – while maintaining robust security measures to safeguard private data.
- **Code of conduct**: Implementing a robust code of ethics – combining automated filtering of offensive content with user reporting mechanisms – is critical to deter harassment, hate speech, and other forms of misuse in virtual environments.[36]

Conclusion

Metaverse Seoul demonstrates that immersive virtual platforms can significantly enhance municipal service delivery, citizen engagement, and local economic development. By replicating physical service environments in the metaverse, integrating AI-driven automation, and adopting robust governance standards, Seoul has established a scalable model for other cities seeking to modernize public services. Future expansions will focus on deepening integration with smart city IoT networks, launching multilingual virtual service desks, and embedding environmental monitoring data to support sustainability initiatives.

Use case 10: Urban air quality monitoring (Horizon 1)

Description

Cities are increasingly adopting digital twin technologies to visualize and manage air pollution in real time. By integrating IoT sensor networks, meteorological data, traffic flows, and land-use information into a 3D digital model, stakeholders can identify pollution hotspots, assess policy interventions, and engage communities in air quality initiatives. Machine learning algorithms predict pollutant dispersion under varying weather and traffic scenarios, while generative AI enables natural-language queries of the data. Municipal agencies, public health departments, and urban planners use these immersive platforms to design targeted mitigation measures – such as traffic restrictions, green corridors, and emissions controls – and simulate their impact on atmospheric conditions and public health.

Impacts

1) **Emission reduction**: Enables precise targeting of major pollution sources through data-driven interventions.
2) **Environmental conservation**: Supports the planning of green infrastructure to absorb pollutants and heat.
3) **Quality of life**: Improves public health by reducing exposure to hazardous air pollutants.
4) **Sustainable urbanism**: Guides land-use decisions that prioritize clean air and active transportation.
5) **Health and wellbeing**: Provides residents with real-time air quality alerts and personalized exposure estimates and supports policy and decision makers to take evidence-based decisions to improve air quality.
6) **Research and innovation**: Offers a living laboratory for testing novel pollutant-control technologies and policies.

Key beneficiaries

- City environmental and public health agencies
- Urban planners and traffic managers
- Residents
- Community and advocacy groups
- Academic and research institutions
- Private sector innovators in clean-air solutions

Key technologies

- **Digital twin**: Real-time 3D model of urban environment fused with live sensor and meteorological data.
- **Mixed reality (MR)**: Immersive visualization for stakeholder workshops and public consultations on air quality plans.

- **AI**: Predictive models for pollutant dispersion, anomaly detection, and optimization of mitigation strategies.
- **GenAI**: Natural language interface enabling lay users to query pollution trends and receive plain-language explanations.
- **IoT**: Networked low-cost and reference-grade sensors capturing $PM_{2.5}$, NO_2, O_3, and other pollutants across the city.

SDG alignment

- **SDG 11: Target 11.6** Reduce the adverse per capita environmental impact of cities.
- **SDG 13: Target 13.2** Integrate climate change measures into policies and planning.

Risk level

Table 10 Risk level: Urban air quality monitoring

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	Monitoring and visualization occur in virtual environments only, posing no direct threat to physical public safety while enabling the earlier identification of pollution hazards and protective measures.
Stakeholder acceptance	Low	Medium	High	Stakeholders, including municipal agencies and community groups, generally embrace data-driven air quality tools, especially when clear benefits for public health and urban planning are demonstrated through pilot projects.
Data privacy and security	Low	Medium	High	If the solution includes combining geolocated air-quality data with demographic or health information this could raise privacy concerns; consequently, strict adherence to data protection regulations and anonymization protocols is essential.
Financial/ operational	Low	Medium	High	Significant initial investment and staff training required; long-term efficiencies justify costs.

Implemented in:

Jakarta, Indonesia; Shenzhen, China; London, UK

Case study – Jakarta Air Quality Digital Twin

Context

Jakarta's rapid urbanization and motorization have created a severe air pollution challenge. With a population of over 11.6 million.[37] Research indicates that air pollution in Jakarta potentially causes more than 10 000 deaths and 5 000 hospitalizations for cardiorespiratory diseases in each year, along with more than 7 000 adverse outcomes in children, and costs more than USD 2.9 billion annually (2.2 per cent of DKI Jakarta's gross regional domestic product).[38]

Traditional air monitoring relies on a sparse network of reference stations, which cannot capture within-neighbourhood variability or short-duration pollution spikes near major roads, hampering the design of effective, place-specific interventions.

Objective

The BINUS University initiative set out to address key limitations of conventional air quality monitoring in Jakarta by developing a city-scale digital twin (DT) integrated with mixed reality (MR) technology. The objectives were to:

- Create an integrated, data-rich 3D model of Jakarta's urban environment.
- Fuse real-time air quality sensor data, meteorological information, traffic patterns, and infrastructure details into this virtual representation.
- Empower decision-makers and stakeholders to visualize pollution in a spatial and temporal context, identify hotspots, and test interventions in a collaborative, immersive environment.
- Enhance transparency, foster community engagement, and support evidence-based urban policy for sustainable development and public health.[39]

Solution approach

The Digital Twin Smart City framework designed by BINUS University incorporated several core elements:

- **Data integration**: Various sources, including real-time air quality sensors, meteorological stations, traffic data, and detailed maps of urban infrastructure, are aggregated and harmonized. This forms the backbone of the DT, reflecting the physical environment and operational conditions of Jakarta in real time.
- **3D Modelling and visualization**: Using advanced computational tools, the DT constructs a 3D, geospatially accurate digital model of Jakarta. Mixed reality (MR) technology overlays pollution concentration maps, wind flows, and other environmental parameters, allowing users to "walk through" digital environments and observe changing conditions from multiple perspectives.
- **Simulation and decision support**: The platform includes capabilities for running "what-if" scenarios – such as simulating the effects of new traffic restrictions, green infrastructure projects, or emission regulations – enabling stakeholders to preview outcomes before actual implementation. MR enhances collaborative exploration and assessment, making complex data and predicted outcomes accessible to a diverse audience.
- **Stakeholder engagement**: City officials, environmental and public health agencies, academic researchers, and citizens are involved in the design and use of the platform. The MR interface is designed for intuitive use, facilitating public consultations, engagement workshops, and cross-sector cooperation around urban air quality management.

(continued)

Case study – Jakarta Air Quality Digital Twin

Results

The prototype digital twin provided city stakeholders with a comprehensive, real-time view of air quality patterns across Jakarta. Early findings included:

- Accurate identification of persistent pollution hotspots in dense urban corridors and near major intersections, enabling prioritization of interventions.
- Rich "scenario playback" capabilities that demonstrated the probable effects of traffic policy changes, industrial restrictions, or new urban green spaces on local air quality.
- Enhanced decision making, with visualizations supporting the allocation of mitigation resources, scheduling of traffic regulation, and targeted public health advisories;
- Engagement of diverse stakeholder groups, fostering transparency and trust in the city's air quality management efforts.[40]

Lessons learned

Lessons learned that can be applied to other air quality or environmental monitoring digital twins include:

- **Integrated data are essential**: The effectiveness of the digital twin depends on continuous, high-quality integration of heterogeneous sources. Challenges regarding sensor calibration, data standardization, and metadata must be solved for the system to be scalable and trustworthy.
- **Visualization accelerates insight**: MR-enabled 3D visualization transforms dense streams of technical data into intuitive and actionable information, empowering a broader range of stakeholders to participate in air quality management.
- **Simulation and collaboration drive value**: Scenario testing within the DT builds evidence for policy and fosters collaboration across agencies, supporting more agile, sustainable decision making.
- **Scaling up requires data governance**: The transition from pilot to citywide deployment hinges on clear protocols for data stewardship, security, and privacy, as well as ongoing investments in digital skill development and infrastructure.
- **Community engagement matters**: Collaborative workshops and interactive visualizations help bridge communication gaps between experts, officials, and the general public, increasing acceptance and effectiveness of air quality initiatives.

Conclusion

The BINUS University Digital Twin for Air Quality represents a significant advance in Jakarta's environmental management toolkit. By combining real-time sensor data, AI-enhanced analytics, immersive 3D visualization, and MR-based user engagement, the initiative demonstrates how cities can build adaptive, data-driven strategies for managing complex urban challenges such as air pollution. The approach offers a replicable blueprint for other megacities seeking to improve environmental quality, public health, and stakeholder participation in the governance of smart cities.

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

Launched by ITU, UNICC, and Digital Dubai, the Global Initiative on AI and Virtual Worlds– *Discovering the Citiverse* is a multistakeholder platform dedicated to shaping the next generation of AI-enabled citiverse[41].

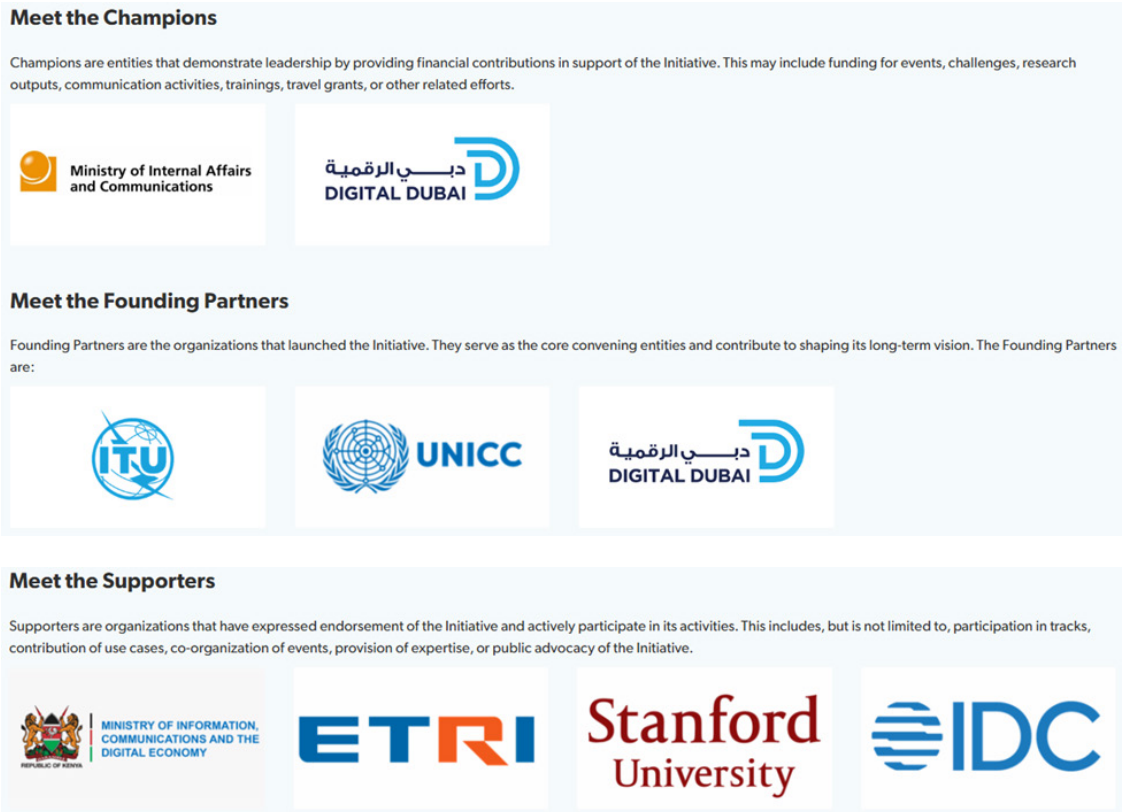
A global coalition of more than 70 partners, including cities, governments, UN agencies, standards bodies, industry, academia and civil society, the Initiative is building the governance architecture of the AI-enabled citiverse.

The Initiative ensures that these technologies evolve in ways that are inclusive, interoperable, and human-centric, while contributing to the implementation of the Pact for the Future and its Global Digital Compact.

Serving as a neutral and action-oriented platform, it brings together public and private stakeholders to advance the responsible development and deployment of the AI-enabled citiverse. It provides blueprints, capacity-building resources, and a global peer network to support cities in moving from vision to scaled implementation.

The Initiative advances its mission through three strategic pillars, supported by dedicated tracks addressing key challenges and opportunities. This structure enables both high-level global guidance and practical implementation across cities worldwide.

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

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