

TOWARDS AN EU ROADMAP FOR AN INCLUSIVE AND SUSTAINABLE CITIVERSE



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Pre-standardization roadmap for an inclusive and sustainable CitiVerse

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SCOPE OF THIS DOCUMENT

The emerging concept of CitiVerse relates to a seamless blending of the physical and digital worlds offering new digital services to digital citizens, allowing also objects to interact with, and respond to, the physical environment in real time. Paul Milgram's virtuality¹ continuum highlights that technology can offer a wide range of experiences, from fully real to fully virtual, and various degrees in between. This mixed reality environment applied to a virtual cityscape or "CitiVerse" offers new perspectives and can enhance various aspects of urban life by converging new technologies, data streams and virtual experiences. However, to turn a city or an urban area into a mixed reality environment, and to make it a liveable environment for *all* citizens will be a complex and ongoing endeavour that requires collaboration among urban planners, technologists, policy makers and content creators.

This short report distinguishes some of the specific issues for cities and communities and potential blockages or challenges that would require attention in the future when building their CitiVerse. It discusses elements to establish a comprehensive EU roadmap for inclusive, citizen-centric, and sustainable CitiVerse, identifying future standardization needs and policy issues that may need further elaboration. It was prepared by several experts and based on an open and wide consultation of the Living-in.eu members, and beyond. It also proposes several definitions and concepts for future discussion as the result of this consultation².

The present document also aims to remove existing obstacles and contribute to future standardisation efforts by offering concrete recommendations derived from potential use cases in smart communities and help the successful development of an EU CitiVerse in the future.

¹ P. Milgram and F. Kishino, "A taxonomy of mixed reality visual displays," *IEICE TRANSACTIONS on Information and Systems*, vol. 77, no. 12, pp. 1321–1329, 1994. The continuum serves as a useful tool for understanding and categorizing different technologies and experiences, helping researchers and developers work with, and explore the possibilities along this spectrum.

² In particular, the document will incorporate input from the findings of the StandICT Landscape on relevant standards and blind areas for the CitiVerse (reference) and from the Living-in.eu technical sub-group (reference).

DEFINITIONS, ABBREVIATIONS AND ACRONYMS

Accessibility [<https://www.w3.org/WAI/fundamentals/accessibility-usability-inclusion/>; the European Disability Forum <https://www.edf-feph.org/an-accessible-disability-inclusive-CitiVerse/>]: degree to which a digital environment, system, or content can be used and accessed by individuals with disabilities, ensuring they can perceive, understand, navigate, and interact effectively and efficiently with the CitiVerse.

Augmented reality (AR): Interactive technology that integrates digital information with the user's physical surrounding in real-time. It enhances the user's perception of real-world objects and environments by overlaying digital sensory inputs onto them. AR can be experienced through a variety of devices, including smartphones, tablets and smart glasses.

CitiVerse³ is a series of interconnected and distributed hybrid and virtual worlds representing, and synchronized with, their physical counterparts. It offers new (administrative, economic, social, policy-making, and cultural) virtual goods/services/capabilities to city and community actors such as citizens, represented as digital avatars.

Data sovereignty [<https://docs.internationaldataspaces.org/ids-knowledgebase/v/ids-g/glossary/>]: The capability of an entity (natural person or corporate) of being entirely self-determined with regard to its data.

Data privacy [GDPR]: means empowering your users to make their own decisions about who can process their data and for what purpose.

Entity [ETSI GS CIM 019 V1.1.1 (2022-08)]: informational representative of something that is supposed to exist in the real world, physically or conceptually.

Inclusion [<https://aliheston.gitbook.io/the-design-of-virtual-and-augmented-reality/the-foundations-of-vr-and-ar/designing-for-accessibility/>]: ensuring diversity and involvement of everyone to the greatest extent possible. It can be referred to as *universal design* and *design for all*. It addresses a broad range of issues including, among the others, accessibility for people with disabilities; access to and quality of hardware, software, and Internet connectivity; education; gender; geographical location; culture, and age, including older and younger people.

³ This definition was first coined in the amendment to the Annex to C(2023) 1862 final Work Programme 2023-2024 in March 2023 and then further defined in the [EU strategy to lead on Web 4.0 and virtual worlds \(europa.eu\)](#). It is inspired on ISO/IEC 23005 and IEEE 2888 standards and also discussed for improvement in the context of the ITU-T Focus Group on CitiVerse, TG on CitiVerse and WG1 on definitions.

Interactivity [Makransky and Petersen, 2021]: the amount of freedom users are given to control their experience in immersive virtual reality, often through handheld controllers and a virtual body.

Immersiveness [Furht, Borko, ed. (2008). Immersive Virtual Reality. In Encyclopedia of Multimedia, Boston, MA: Springer US, pp. 345–346]: technology that aims to completely immerse the user inside the virtual worlds, giving users the impression they have "stepped inside" the synthetic world.

Internet of things (IoT) [b-ITU-T Y.4000]: A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.

Interoperability [ITU-T Y.101]: interoperability is the ability of two or more systems or applications to exchange information and to mutually use the information that has been exchanged.

Model training [<https://c3iot.ai/glossary/data-science/model-training/>]: Model training is the phase in the data science development lifecycle where practitioners try to fit the best combination of weights and bias to a machine learning algorithm to minimize a loss function over the prediction range.

Openness means that anyone can freely access, use, modify, and share for any purpose (subject, at most, to requirements that preserve provenance and openness).

Personal data [GDPR]: means any information relating to an identified or identifiable natural person ('data subject'); an identifiable natural person is one who can be identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, an online identifier or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person.

Security for the CitiVerse refers to the practises and measures to ensure the safety, privacy, and integrity of individuals, data, and systems within the CitiVerse.

Sustainability [FG-MV-WG8-I-TG-design-002]: a CitiVerse is sustainable when it is designed to: (a) address present environmental and societal needs without compromising the ability of future generations to meet their own needs, and (b) harness system benefits for the environment, people and stakeholders while preventing any type of harm to them and mitigating unintended sustainable impacts.

Trust is the degree of confidence that stakeholders have in the data, services, technology, algorithms, and other stakeholders of a CitiVerse platform, including the CitiVerse platform as a whole.

Universal design [<https://design.ncsu.edu/research/center-for-universal-design/>]: design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design.

Virtual worlds: Persistent, 3D, real-time, immersive environments, blurring the line between real and virtual, for socialising, working, learning, making transactions, playing, participating and creating.

Web 4.0: 4th generation of the World Wide Web where physical and digital worlds are seamlessly blending, enabling more intuitive and immersive experiences. Making use of advanced artificial and ambient intelligence, internet of things, virtual worlds and extended reality capabilities, web, real objects and environments are fully integrated and communicating between each other through more collaborative, decentralised and user-centered approaches.

INTRODUCTION

The European CitiVerse (or citiverse) is a flagship project of public interest. It aims to improve citizen's experience in hybrid virtual worlds mixing both virtual and physical realities. It can also enhance spatial planning, social interactions, or urban management by considering social, architectural, sustainable, and cultural dimensions.

The European Commission has developed an important strategy on this topic, building on research projects, public consultations, and industry initiatives⁴. On the 24th of March 2023, a new action was launched under the Digital Europe (DEP) work programme 2023⁵ to help define what the 'CitiVerse' means for Europe, building on the smart communities' data infrastructure that is developed under previous DEP work programmes. On the 11th of July, the Commission adopted a Communication on "An EU initiative on web 4.0 and virtual worlds: a head start in the next technological transition"⁶, to steer the next technological transition and ensure an open, secure, trustworthy, fair and inclusive digital environment for EU citizens, businesses and public administrations. The strategy builds on previous work of the European Commission on virtual worlds and consultations with citizens, academia and businesses⁷. It has been accompanied by [an EC Staff Working Document](#).

Based on this, it became apparent that these new developments will require various steps and technologies to be deployed to meet the objectives of the Communication⁸. In this strategic context, the Living-in.eu community has embarked on a thorough exploration centred on a CitiVerse *for* citizens and shaped also with the purpose of unifying EU industry, including Small and Medium-sized Enterprises (SMEs) around the same vision. The objective is to foster collaboration and amplify the capabilities of local digital twins. This introspective journey has yielded a collaboratively crafted pre-standardization roadmap, meticulously conceived to steer the development of an inclusive and sustainable CitiVerse.

⁴ [EU strategy to lead on Web 4.0 and virtual worlds \(europa.eu\)](#)

⁵ COM(2023) 1862 final

⁶ European Commission (EC) (2023). *An EU initiative on Web 4.0 and virtual worlds: a head start in the next technological transition*. COM(2023) 442/final COM(2023) 442/final

⁷ Including two important reports of the JRC: Hupont Torres, I., Charisi, V., De Prato, G., Pogorzelska, K., Schade, S., Kotsev, A., Sobolewski, M., Duch Brown, N., Calza, E., Dunker, C., Di Girolamo, F., Bellia, M., Hledik, J., Nai Fovino, I. and Vespe, M., *Next Generation Virtual Worlds: Societal, Technological, Economic and Policy Challenges for the EU*, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/51579, JRC133757.

⁸ [EU strategy to lead on Web 4.0 and virtual worlds \(europa.eu\)](#)

The experts involved, supported by the Living-in.eu community and by the [StandICT project](#) analysed the specific challenges to create an open, inclusive, and sustainable CitiVerse for Europe. This guide not only states the potential impact of the CitiVerse on citizens' lives but also serves as a valuable instrument for its seamless deployment. Significantly, it draws inspiration from ongoing initiatives within the DIGITAL Europe Programme, further aligning with the forward-looking trajectory of smart communities. The question of available open standards remains also crucial. Therefore this pre-standardisation roadmap identifies key areas where technological and policy initiatives would be needed, and aims to propose high-level recommendations to industry, policy makers as well as standardisation bodies.

The authors envision this initiative as a necessary step toward creating an inclusive, citizen-centric, and sustainable CitiVerse within the European Union.

VISION STATEMENT

The European Union aims to promote an inclusive and sustainable CitiVerse, setting leading benchmarks for equality, openness, decentralized governance, sustainability, and well-being (COM 442/Final, 2023)⁹. The CitiVerse must be designed and developed on decentralised, technology-agnostic, open, user-centric, and accessible platforms and reflect the values, principles, and fundamental rights of the EU. The aim is to create **citizen's centric environments** where consumers, workers, and/or creators are respected, and European businesses can thrive, scale, and grow. It should offer opportunities to public authorities and urban planners to better serve their citizens and meet larger societal purposes such as climate change and biodiversity, as well as make use of evidence-based decisions using Web 4.0 technology. Open standards and interoperability between networks and platforms are essential to ensure user freedom, digital ownership, cross-platform activities, and economic opportunities. Competition and innovation among providers need to be sustained for CitiVerse ecosystems to become more diverse and richer.

⁹ Idem COM(2023) 442/final

OPPORTUNITIES AND CHALLENGES

In the years ahead, the CitiVerse is expected to be an important component of the Digital Decade policy program¹⁰, through which the European Commission aims to pursue a “human-centric, sustainable vision for digital society throughout the digital decade to empower citizens and businesses.” The main goals can be summarized in these four points:

1. a digitally skilled population and highly skilled digital professionals;
2. secure and sustainable digital infrastructures;
3. digital transformation of businesses;
4. digitalization of public services.

The CitiVerse should improve quality of life in cities by addressing economic, social and environmental challenges, such as smart cities, green infrastructure, sustainable transportation, community engagement and education and healthcare, to name a few. Driven by today’s environmental and societal challenges, the development of the CitiVerse has connections and implications for the achievement of the Sustainable Development Goals (SDGs), the European Green Deal, and the initiatives for EU cities and urban development¹¹. Building on the interconnection of existing Digital Twins currently developed across the EU, Smart Cities will create the foundation for an EU CitiVerse based on the EIF4SSCC principles¹². The future CitiVerse could also be integrated into the Society 5.0¹³ framework, which represents a shift to an ideally just and sustainable society, achieved by a high degree of convergence between cyberspace and physical space. The idea of Society 5.0 is to leverage people’s well-being through cutting edge technology, therefore the CitiVerse may play a significant role in this Society.

Some opportunities¹⁴ as mentioned in the use cases around the CitiVerse:

¹⁰ Decision (EU) 2022/2481 of the European Parliament and of the Council of 14 December 2022 establishing the Digital Decade Policy Programme 2030.

¹¹ https://commission.europa.eu/eu-regional-and-urban-development/topics/cities-and-urban-development_en

¹² <https://op.europa.eu/en/publication-detail/-/publication/f69284c4-eacb-11eb-93a8-01aa75ed71a1/language-en>

¹³ https://www8.cao.go.jp/cstp/english/society5_0/index.html

¹⁴ For an extensive description of opportunities across different sectors, please refer to Hupont Torres, I., Charisi, V., De Prato, G., Pogorzelska, K., Schade, S., Kotsev, A., Sobolewski, M., Duch Brown, N., Calza, E., Dunker, C., Di Girolamo, F., Bellia, M., Hledik, J., Nai Fovino, I. and Vespe, M., Next Generation Virtual Worlds: Societal, Technological, Economic and Policy Challenges for the EU, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/51579, JRC133757

- Smart cities can use virtual worlds for urban planning and simulation. City planners can simulate and test scenarios before implementing them in the real world, supporting decision making to optimize infrastructure and services. They can also engage citizens in the planning and decision-making processes of a city.
- Smart communities can integrate real-time data from various data sources such as sensors, IoT devices to create interactive environments, new assets and offering them new possibilities.
- Authorities can create digital twins of physical cities, providing real-time information of city's functioning.
- It can also reduce the need for citizens mobility, bringing remotely located people and objects together and breaking existing physical and political boundaries.

While offering numerous opportunities, the CitiVerse also poses several challenges that require regulatory attention. The European Parliament has already pointed out in a briefing some risks and policy implications for virtual worlds¹⁵. In the context of the CitiVerse, there are common, but also specific challenges to look at, among them:

- Societal challenges: new social norms and inclusion aspects, tri-dimensional content moderation, poly-accessibility, mental health, child safety, etc.
- Economic challenges: infrastructure requirements, intellectual property, virtual assets, virtual economy rules, etc.
- Environmental challenges: One or many CitiVerses can be intensive in terms of resource consumption but also blur physical realities and laws. Citizens need to know and understand the environmental impacts of the CitiVerse and their related activities and ensure they continuously contribute to the green transition.
- Technical challenges: Data sharing and portability, data privacy and security, like avatar integrity, computing and networking capacity, seamless interactions and computer vision, cross-platform interoperability, etc.
- Governance and policy challenges: Legal issues, identity, liability, security of enabling devices and protocols, ethical and policy considerations.
- The concept of interoperability and the flow of users within and among various CitiVerse implementation, along with their data and assets, give rise to inquiries about data sharing and data portability.

¹⁵ [https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/733557/EPRS_BRI\(2022\)733557_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/733557/EPRS_BRI(2022)733557_EN.pdf)

USE CASES FOR CITIES (EXAMPLES)

Methodology

Smart cities in the CitiVerse can encompass a diverse array of use cases, spanning various categories: urban planning, mobility, energy and environmental sustainability, citizen engagement and services, public safety, education, wellbeing, cultural and economic development, etc. In order to formulate a community supported definition of the CitiVerse and generate a diverse set of useful use cases to advance the development, the following methodology has been applied in the context of Living-in.eu meetings.

The community launched an activity to understand how a Citizen-centric CitiVerse should be defined and what new or transformed applications could it enable in the urban realm.

First, background research has been conducted to clarify the fundamentals of the CitiVerse idea. The concepts were divided into two parts: “Citi” and “Verse.” What are cities and their communities working on? What are virtual world technologies? What do they enable? What can they improve? Both dimensions were then used as a basis to create a multidimensional matrix. The matrix development and usage can be found in annex I.

Secondly, the matrix allowed to gather and map out existing best practices and potential use cases out of expert publications. Based on this, the community were able to adapt commercial use cases to an urban or regional application. The matrix development can be found in annex I.

Thirdly, a broader group of actors gathered together via the Living-in.eu network and the technology sub-group to enrich and prioritize the proposed use cases based on needs and impact. The matrix application can be found in annex I.

Finally, a small group of experts plotted out a feasibility timeline taking into account the complexity of each use case, the available data and the change entailed.

Use Cases Proposition

The CitiVerse starts with a digital representation of a city, relies on real-time data from sensors, cameras, and IoT devices to provide residents with real-time insights into their urban environment. This data helps in informed decision-making about commuting, health, and lifestyle. CitiVerse also serves as a valuable tool for urban management and decision-making, enabling simulation and analysis

of scenarios like infrastructure projects and zoning regulations. It also enhances safety and security by identifying potential hazards and enabling rapid responses from law enforcement. Through research and a dedicated workshop, several possible use cases were briefly formulated which can be found in the Annex I. In addition to new use case ideas many best practices in the field of tourism have been listed. A small number of use cases need to be defined further.

The visual below shows an extraction of the most desirable cases divided in order of feasibility.

Prioritized Use Cases Proposition		
<u>Quick-Wins</u>	<u>Middle-term</u>	<u>Longer-term</u>
Virtual tourism	Urban heat islands	Traffic control rooms
Real-time situational awareness	Public virtual safety	Evidence-based policy in real time (emergency services)
Gather feedback through virtual objects	(Show) Simulate urban floods, traffic patterns... (ldt)	Emergency training citizens
	Engage on adaptations to urban env.	

KEY RELEVANT ASPECTS OF THE CITIVERSE

This section provides a high-level overview of essential features and pertinent elements crucial for constructing the CitiVerse. It encompasses both the vertical dimension, focusing on technologies, and the horizontal dimension, which delves into key enablers. The content herein serves as a reference for further discussion, offering insights into the foundational components essential for the development of the CitiVerse.

Vertical dimension



Crafting a robust CitiVerse for citizens necessitates a thorough examination of technology considerations, acknowledging the gradual evolution and varying levels of maturity in the technological landscape. The CitiVerse relies on a multitude of core enablers, each playing a pivotal role in shaping its functionality and user experience. At the foundation of these enablers lies hardware, encompassing physical devices such as headsets and mobile phones that serve as gateways to access, interact with, or contribute to the CitiVerse. *Networking* forms the infrastructure facilitating seamless data transmission, ensuring connectivity across virtual landscapes. *Computing power* is integral for processing the vast amounts of data generated within the CitiVerse. *Virtual data platforms* provide the immersive environments where users engage with the digital space, while *tools* and *standards* establish the benchmarks for interoperability and continuous enhancement of the CitiVerse. *Payment mechanisms*, inclusive of digital currency exchanges, cryptocurrencies like bitcoin, and blockchain technologies, underpin the financial aspects of the CitiVerse. Moreover, content, services, and assets introduced by third-party entities contribute to the CitiVerse, enriching the digital landscape beyond the confines of platform ownership.

Indubitably, these core enablers are evolving at different paces and levels of maturity. As technology advances, the CitiVerse's success hinges on the harmonious development and integration of these components. Therefore, a strategic focus on openness, decentralized architecture, interoperability, and resilience is imperative to navigate the evolving technological terrain and ensure the CitiVerse becomes a truly inclusive and dynamic digital frontier for citizens.

NETWORKS

Scope and references:

High-speed networks must support decentralised, technology-agnostic, open, user-centric, and accessible platforms underpinning CitiVerse services to be in line with the vision of this document. The

CitiVerse is a multi-technological infrastructure that requires a comprehensive governance model encompassing algorithmic, business, and social governance for accessibility and responsibility coverage. Networking capacity to support this can have centralized or decentralized governance models and architectures, with parallel and distributed systems, but hybrid approaches are also emerging for complex environments.

Among the envisioned **requirements**, we can mention:

Building a resilient CitiVerse requires going beyond key networking requirements to facilitate seamless and reliable user experiences. A low-latency infrastructure, for instance is paramount for real-time interactions, ensuring that users can engage in virtual environments without noticeable delays. High bandwidth is crucial to support the transfer of data-intensive content, such as high-quality graphics and audio, contributing to a smooth and immersive CitiVerse. Reliable connectivity, scalability to accommodate a growing user base, and robust security protocols are vital components, safeguarding user data and privacy against cyber threats. The global reach of networking infrastructure fosters inclusivity by allowing users from diverse geographical locations to participate in the CitiVerse. Standardized, MIM-compliant interoperability protocols and adaptive network management systems should enhance the overall resilience, ensuring compatibility between various virtual platforms and dynamic adjustment to changing user activity and traffic patterns. Incorporating redundancy and failover mechanisms further fortifies the CitiVerse against potential network failures, guaranteeing secure and uninterrupted access and a dependable digital environment for citizens.

EDGE/ CLOUD

Scope and references:

Large scale multimedia needs will require a combination of substantial computational structures capable to scale and offer real synchronicity and persistence services. Computing capacity will be multifaceted and demanding a sophisticated infrastructure to support the complex interactions, simulations and data processing inherent to this new digital environment.

Among the envisioned **requirements**, we can mention:

- Processing power to render high-quality graphics, simulate dynamic environments and handle real-time interactions.

- Solutions such as edge¹⁶ and cloud computing¹⁷ that differ primarily in their application requirements and trade-offs involving factors like resource location, scalability, latency, security, and management but will require to interoperate.
- The necessity to combine powerful hardware capacity with distributed computing architectures, AI capability and scalable storage solutions, while carefully addressing the carbon footprint and other environmental concerns newly created by these extraordinary energy-consuming devices.

DATA

Scope and references:

The CitiVerse paradigm stems from existing data platforms evolving towards distributed systems replicating and interacting with the physical realm. The EU Data Space for Smart Cities and Communities blueprint¹⁸ adopted the Living-in.eu principles and specifications and refers to minimal interoperability mechanisms (MIMs Plus¹⁹) proposed by the Living-in.eu movement²⁰ to foster a thriving European digital market. DS4SSCC is also aligned with the EU Data Space Support Centre proposed taxonomy of [building blocks](#) and framed by the EU initiative on data spaces.

Among the envisioned **requirements**, we can mention:

- Data spaces leverage on data sharing, so data is the essential material to feed the CitiVerse. Implementing CitiVerse requires a diverse set of data that spans various aspects of urban life and infrastructure. These data requirements are essential for creating a comprehensive and functional digital representation of a city.

¹⁶ Edge computing relies on distributed resources in proximity to end-users, forming edge networks. It prioritizes reduced latency and real-time or near-real-time responses for applications like IoT, autonomous vehicles, and augmented reality. It doesn't rely on centralized data centres.

¹⁷ Cloud computing focuses on security and invests heavily in cybersecurity and cyber-resilience measures. It offers scalable resources on demand to users. In contrast, edge computing scales horizontally, adding transversal capacities to networks while managing potential security vulnerabilities.

¹⁸ <https://www.ds4sscc.eu/technical-blueprint>

¹⁹ Minimal Interoperability Mechanisms (MIMs)¹⁹ are universal tools for achieving interoperability of data, systems, and services between cities and suppliers around the world. Because the mechanisms are based on an inclusive list of baselines and references, they take into account the different backgrounds of cities and communities and allow cities to achieve interoperability based on a minimal common ground

²⁰ The DS4SSCC catalogue of specifications is available here: [D3.1 Catalogue of Specifications pdf.pdf - Google Drive](#)

- CitiVerse data comprises various categories, each serving a unique purpose in enhancing urban life like Geospatial Data, Real-time Sensor Data, IoT Device Data, Data on the various areas of managing a city (Environmental, Transport, Energy, Emergency Services, Economic, Cultural and Heritage Data...).
- These data requirements form the foundation for creating a dynamic and responsive CitiVerse that accurately reflects the city's present state, facilitates data-driven decision-making, enhances citizen engagement, and fosters sustainable urban development. Proper data management, integration, and analysis are essential to realize the full potential of CitiVerse.
- The main challenge for the CitiVerse is data interoperability and connectivity in an area that it is at a crossroad of many different sectors. The first step is to achieve an EU Smart Cities Data Space and ensure its wide adoption by relevant players.

LOCAL DIGITAL TWINS

Scope and references:

Local digital twins (LDTs) are a virtual representation of the physical assets, processes and/or people within a geographically located community, which reflect and derive from cross-sectorial, historical and (near) real-time data.

Among the envisioned **requirements**, we can mention:

- To build CitiVerse use cases and services on top of Local Digital Twins, the first step for many cities is to improve data collection, retention, quality, integration and analysis capabilities, and then add the XR visualization. AR/ VR features could typically be implemented over existing urban data platforms or Digital Twins, that will provide the underlying capacities that are needed.
- A certain level of maturity is needed. The DUET maturity model recognizes that at earlier stages of maturity open data, data interoperability and data platforms are the key technology building blocks of a Local Digital Twin.
- LDTs can be at various levels of complexity and value and present a varied set of capabilities that need to be fulfilled e.g strategy, security, IoT, legal, etc.

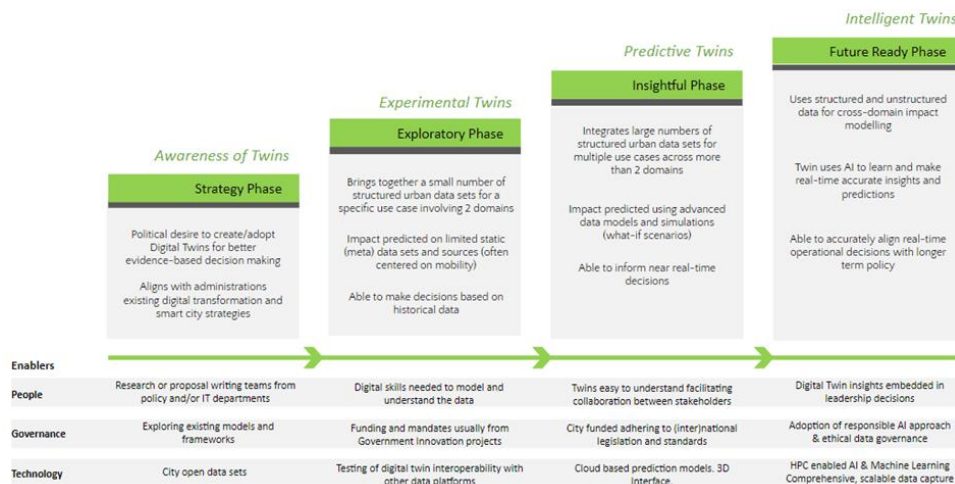


Image illustrating the classification criteria related to the four maturity levels. The [DUET Digital Twin Maturity Model](#) relies on four classification criteria: Level 1 – Awareness of Twins, Level 2 – Experimental Twins, Level 3 – Predictive Twins, Level 4 – Intelligent Twins

DISTRIBUTED LEDGER TECHNOLOGIES

Scope and references:

Blockchain's key attributes are paramount for the CitiVerse since it allows for decentralised architectures for platforms and governance. Depending on the type of CitiVerse services that will be unfolding in the future, such as crypto assets or cryptocurrencies, the specific requirements stemming from these technologies are yet to be defined but should allow for scalable solutions processing more transactions without compromising efficiency. In any case, by being implemented in a decentralised manner, the CitiVerse will have to support interoperability among various ledgers through the adoption of recognised international standards²¹.

Among the envisioned **requirements**, we can mention:

- Decentralization: A foundational principle for a CitiVerse is decentralization, which entails distributing control and ownership across a network of nodes. Utilizing a decentralized

²¹ The ITU's FG-DLT efforts have influenced other standardization organizations, such as ISO TC 307 and ETSI ISG PDL, Blockchain and Distributed Ledger Technology (DLT). ISO TC 307 has developed standards covering security, privacy, governance, and other aspects, while ETSI ISG PDL addresses inter-ledger interoperability.

blockchain ensures that no single entity has absolute authority, fostering a more democratic and equitable virtual space.

- Smart Contracts: Smart contracts are self-executing contracts with the terms of the agreement directly written into code. In a CitiVerse, smart contracts can automate transactions, enforce rules, and facilitate various interactions among users, virtual assets, and the environment.
- Tokenization: A well-designed *tokenomics* model defines the distribution and utility of the native cryptocurrency or tokens within the CitiVerse. It can incentivize user engagement, content creation, and contribute to the overall economic sustainability of the virtual ecosystem.
- NFT (Non-Fungible Token) Standards: NFTs are unique digital tokens that represent ownership or proof of authenticity for virtual assets. Implementing NFT standards such as ERC-721 or ERC-1155 on the blockchain enables the creation and trade of distinct and indivisible virtual items within the CitiVerse.
- Cross-Platform Compatibility: Ensuring cross-platform compatibility allows users to access the CitiVerse from various devices and platforms. Blockchain features that facilitate smooth integration with different technologies and environments contribute to a more inclusive and accessible virtual experience.
- Consensus Mechanisms: The choice of a consensus mechanism, such as Proof of Stake (PoS) or Proof of Work (PoW), impacts the security and efficiency of the CitiVerse. The selected consensus mechanism should align with the goals of decentralization, security, and energy efficiency.

Other features concern privacy and security to protect data and virtual assets, community-driven governance models on the blockchain, digital ownership, and decentralized consensus, enhancing trust and enabling seamless interaction with other technologies.

ARTIFICIAL INTELLIGENCE

Scope and references:

Sara Takamasu²² says in her report on that “the main characteristics of synchronicity, persistence and interoperability prompt the public to have high hopes for the CitiVerse especially due to the current

²² S. Takamatsu “Avoiding public failure of the CitiVerse”.

limitations of the internet”. Artificial Intelligence (AI) is playing a key role in boosting all the layers of the CitiVerse (from web 3.0 to web 4.0) significantly enhancing various aspects of virtual environments and user experience. AI technology can boost many functions of the CitiVerse, both technical, or application-related such as the user experience, the spatial computing, decentralisation, human interfacing or infrastructure. Through machine-learning solutions it will boost decision-making by computers, improve (multilingual) accessibility, avatar management, and generate large amounts of data that can provide valuable insights and automation for users.

In the context of CitiVerse, AI models face several challenges.

- **Adaptivity to Dynamic Data Sources:** CitiVerse data sources constantly change due to factors like IoT issues, stakeholder availability, and data sovereignty requirements. Models must adapt gracefully as data sources become unavailable.
- **Knowledge Transfer Across Entities:** AI models predicting properties of CitiVerse entities should be transferable to similar entities, but variations in available data sources pose a challenge. Models need to handle discrepancies and new data sources effectively when transferring knowledge.
- **Handling Limited Model Quality:** Data source volatility can result in uncertain prediction quality. Models must provide not only predictions but also confidence levels, especially as data sources shift. This complexity adds to challenges like data drift, overfitting, and underfitting.
- **Improving Quality Over Time:** CitiVerse ML models should enhance their quality with longer timeseries data, emphasizing continuous improvement.

A large survey²³ on *AI in the CitiVerse* proposed a comprehensive investigation of AI-based methods concerning several CitiVerse-related aspects such as natural language processing, machine vision, blockchain, networking or digital twin. But applying and optimising AI techniques to polish the appearance of the virtual world will not be enough, to bring also quality in the CitiVerse, AI will have to meet a number of specific requirements. In short, a lot of research is needed to serve the many purposes from hyperreal objects and landscape rendering to human-like interactions that the CitiVerse will require.

Among the envisioned **requirements**, we can mention:

For modelling approaches:

- Cognitive modelling will be needed to better analyse and predict how users interact with their virtual environment, with a focus on processes like perception, memory, attention,

²³ <https://doi.org/10.1016/j.engappai.2022.105581>

learning, decision-making, and social interaction. The goal is to create intelligent virtual agents that behave acceptably and compatibly with digital avatars representing human users.

- Human modelling (to represent human users through digital avatars) in real-time, enabling realistic interactions with other users will include many challenges (involves modelling various aspects of a person, from cognitive and physical traits to psychological, social, behavioural factors, preferences, values, and skills) and secure data management to formalize and interpret human aspects for use in the CitiVerse.
- Temporal modelling to understand the city's evolution and adapt to events will have to track historical trends, provide real-time updates, and generate predictive analytics. It should allow event simulation, optimized resource allocation, aid emergency response, and encourage citizen engagement in the CitiVerse. Temporal modelling will also inform the design of adaptive infrastructure, such as traffic management systems or flexible energy grids.

These approaches enhance CitiVerse's ability to adapt, evolve, and provide valuable insights for sustainable urban development, ensuring the digital representation remains dynamic and responsive to the ever-changing urban environment. Also, in a hybrid environment such as the CitiVerse, it will be important to enhance the *interpretability* and *explainability* capabilities of those models to provide trust and understanding to citizens.

COMPUTER VISION

Scope and references:

Computer vision technology significantly improves CitiVerse immersion by enabling realistic avatars, natural interactions, spatial awareness, and dynamic adaptation to real-world conditions. These advancements contribute to a more engaging and authentic virtual experience for users, revolutionizing urban management and interaction. In the urban realm, it enhances the different virtual worlds for instance by creating hyper-realistic 3D city models or by integrating cameras, sensors, and drones, empowering citizens, planners, and policymakers with immersive, up-to-date views.

Among the envisioned **requirements**, we can mention:

- Safety improved with real-time monitoring, incident detection, and training simulations, benefiting both law enforcement and citizens.
- Realistic avatar expressions, natural interaction, and gesture recognition to enhance social and environment interactions making them lifelike and engaging.
- Object and environment (dynamic) recognition, including spatial awareness should be realistic and mimic the physical environment as to recognise enhanced reality objects and

adjust to real-life conditions (e.g., light or weather changes). It should allow for the blending of the virtual and real-world elements (augmented reality overlays), so that users can interact with element superposed on the real world, creating mixed-reality experiences.

- Hybrid applications such as virtual town hall meetings and consultations, making decision-making more inclusive and responsive to residents' desires, redefining urban evolution.

ELECTRONIC IDENTITY MANAGEMENT

Scope and references:

A reliable electronic identity management system will be absolutely essential in the CitiVerse to ensure that user's identities are secured and protected and to provide certainty to businesses and public organisations when users access digital services. The Regulation on electronic identification and trust services²⁴ for electronic transactions in the internal market (eIDAS Regulation) stands as a cornerstone in creating a regulatory environment that guarantees predictability and security for electronic transactions in the EU. It allows the use of national electronic identification schemes (eIDs) to access online public services across EU countries. The first version of a common framework to implement the EU Digital Identity Wallet (eWallet) was launched on 10 February 2023²⁵ and it will provide several advantages in the CitiVerse for moving between virtual environments. The eWallet will instil confidence in the legal validity of electronic services and digital interactions and play a crucial role in enhancing CitiVerse authentication services in several ways.

Among the envisioned **requirements**, we can mention:

- Cross-border interoperability and authentication: In the CitiVerse context, this cross-border authentication enables users to effortlessly access virtual environments, platforms, and services, regardless of their physical location. It can lead to standardized authentication mechanisms within the CitiVerse, allowing citizens to potentially utilize their national electronic IDs for authentication across diverse virtual platforms and applications, irrespective of geographical location. This will promote a more user-friendly and integrated CitiVerse experience, akin to the concept of the free movement of persons in the Schengen Agreement.
- Secure user identity verification and protection: The eIDAS Regulation emphasizes the protection of digital identities and personal data and ensures a secure foundation and

²⁴ [Regulation on electronic identification and trust services](#)

²⁵ For more information please read: [EU Digital Identity Wallet Toolbox Process | Shaping Europe's digital future \(europa.eu\)](#)

trustworthiness for user identity verification in the CitiVerse. This is particularly important for activities such as virtual transactions, social interactions, and accessing personalized content and to create and use digital avatars or representations.

- Unified standards for trust services: The eIDAS Regulation sets for standardized norms for trust services, guaranteeing their legal status on par with conventional paper-based equivalents. Within the CitiVerse, this legal parity has the potential to bolster the credibility and reliability of authentication services, promoting user confidence in the virtual space and allowing for the delivery of public services online.
- Legal recognition for virtual transactions: The eWallet can extend to virtual transactions within the CitiVerse, guaranteeing that authenticated identities and transactions carry legal significance. This will contribute to the establishment of a secure and regulated environment for virtual commerce, trade of digital assets, and other digital interactions.

XR REALITY, VIRTUAL AND REAL-WORLD INTEGRATION

Scope and references:

The CitiVerse is an immersive environment with a strong connection to the real world through digital twins. By combining digital technologies and devices, users will access new virtual worlds to live enhanced experiences of reality and create new digital assets. In its science for policy report on ‘Next Generation Virtual Worlds: Societal, Technological, Economic and Policy Challenges for the EU’²⁶, the JRC refer to ‘next generation virtual worlds’ as the current and future evolution of what we are observing in the field of ‘eXtended reality (XR)’ user experiences. In particular, they describe the relevance of XR as a very relevant facet to facilitate policy-making with citizen participation, for example, by ‘[increasing] citizens’ participation in decision-making, by letting them experience in the CitiVerse different policy options; to model the possible consequences of certain policy choices; and to gather behavioural insights on how citizens would interact with changes in their local environment.’ The report underlines that ‘a CitiVerse can be useful at different scales, ranging from immersive visualisation of cities/communities for a specific short-term check, to more long-term visualisation and simulation of complex policy decisions that affect several interwoven sectors.” However, there are

²⁶ <https://publications.jrc.ec.europa.eu/repository/handle/JRC133757>

many technical limitations and research gaps that need to be overcome as described in the European Commission JRC study on Extended reality²⁷.

Among the envisioned **requirements**, we can mention:

- The quest for immersion creation in the CitiVerse might require leveraging AI to accelerate scene generation and address challenges related to capturing real-world scenes, updating virtual environments, and fostering a shared sense of immersion²⁸. The intersection of computational imaging and AI holds immense potential for advancing CitiVerse technologies and delivering heightened levels of immersion to its users²⁹.
- Creating immersion involves also the art of constructing a three-dimensional virtual world that engulfs human beings in a captivating and engaging experience³⁰.
- AI scenes often lack realism due to predefined elements, hindering immersion. Innovation in sensing, sampling, and scene generation is essential to address this. Also, real-world scene capture, and computational imaging are discussed as solutions for real-time updates and enhanced immersion in CitiVerse.
- User Interfaces are another area of development for which massive innovation will be needed if we want the CitiVerse to become inclusive and to scale up across Europe. One of the challenges is to design large scale end-user devices that can be used by citizens and organisations to navigate the CitiVerse.
- Text interpretation will also play a crucial role in CitiVerse communication. There is significant need for enhancing the capabilities of natural language processing³¹, an extensively supported research domain within AI. In the CitiVerse, natural language processing applications will have to focus on novel dialogue systems to maintain a record of social activities. There will be a need for AI-based assistants to effectively assist citizens and organisations in managing their interactions. Besides, in a hybrid society, where people from

²⁷ European Commission, Directorate-General for Communications Networks, Content and Technology, Boel, C., Dekeyser, K., Depaepe, F. et al., Extended reality – Opportunities, success stories and challenges (health, education) – Final report, Publications Office of the European Union, 2023, <https://data.europa.eu/doi/10.2759/121671>

²⁸ [Storytelling and user experience in the cultural CitiVerse - ScienceDirect](#)

²⁹ The role of AI to improve immersion in virtual worlds is well explained in the “Roadmap toward the CitiVerse: An AI perspective”, <https://doi.org/10.1016/j.xinn.2022.100293>

³⁰ See for example study in the area of learning ([Full article: Learner immersion engagement in the 3D virtual world: principles emerging from the DELVE project \(tandfonline.com\)](#)) or learning or culture ([Full article: Developing experiences: creative process behind the design and production of immersive exhibitions \(tandfonline.com\)](#))

³¹ [The Power of Natural Language Processing \(hbr.org\)](#)

diverse backgrounds and even different eras coexist, a new AI-powered application will be needed to facilitate communication and interaction among people with varying experiences and contexts³².

- In the same vein, sound will be ubiquitous in the CitiVerse, and spatial audio enhances the auditory environment and supports real-time control of media content and the experience³³. AI-driven audio management will be instrumental in delivering an immersive auditory experience in this virtual realm³⁴. Voice, being a vital interface for human interaction in this virtual realm, will probably serve as the primary mode of communication between avatars, digital humans, and even non-human objects. Voice processing encompasses two essential tasks: automatic speech recognition and text-to-speech conversion (or speech synthesis), which involve transforming voice signals into text and vice versa³⁵. When combined with language understanding techniques, automatic speech recognition and text-to-speech enable entities within the CitiVerse to comprehend others' messages and intentions and respond as if they were in the real world.
- Furthermore, audio signals can be rendered as binaural signals³⁶, allowing humans to perceive the location of sound sources and the presence of enclosed spaces, thereby creating a sense of auditory immersion³⁷. However, achieving auditory immersion in the CitiVerse presents numerous challenges that require advanced signal processing and machine learning techniques. These challenges include separating virtual world sounds from real-world sounds, developing customized speech synthesis, generating complex 3D soundscapes, and more. Future research and innovation will be needed to address these challenges and helping managing audio within the CitiVerse³⁸.

³² [The Power of Natural Language Processing \(hbr.org\)](https://hbr.org)

³³ [Frontiers | Interactive Audio Augmented Reality in Participatory Performance \(frontiersin.org\)](https://frontiersin.org)

³⁴ [An Introduction to Audio, Speech, and Language Processing \(appen.com\)](https://appen.com)

³⁵ [Speech AI Concepts You Should Know | NVIDIA Technical Blog](https://www.nvidia.com/en-us/technical-blogs/speech-ai-concepts-you-should-know/)

³⁶ Binaural signals are typically created using specialized recording techniques that mimic the way human ears perceive sound. When these signals are played back through headphones or earphones, they can create a three-dimensional audio perception, allowing the listener to perceive sounds as if they are coming from specific directions and distances in a virtual or simulated environment. This technique is commonly used in virtual reality (VR), augmented reality (AR), gaming, and other immersive audio applications to enhance the sense of realism and spatial immersion for the user. (ref: ChatGPT)

³⁷ [PDF\) Rendering binaural signals for moving sources \(researchgate.net\)](https://www.researchgate.net/publication/351111111)

³⁸ [Roadmap toward the CitiVerse: An AI perspective: The Innovation \(cell.com\)](https://www.cell.com)

Horizontal dimensions



As part of the activities towards a European Commission communication on “*An EU initiative on Web 4.0 and virtual worlds: a head start in the next technological transition*”, a panel identified eight citizen values & principles for desirable and fair European Virtual Worlds, namely freedom of choice, sustainability, human centred, health, education and literacy, safety and security, transparency and inclusion.

These are targeted values encompassing open, secure and human-centric access to technology. A group of experts have identified other complementary key enablers or principles that are paramount for an inclusive and sustainable CitiVerse.

TRUST

Scope and references³⁹

This section outlines trust considerations for CitiVerse.

Among the envisioned **requirements**, we can mention:

- A CitiVerse platform shall be auditable, that is, it shall undergo the assessment of the system’s technologies, algorithms, data, and design processes. This does not necessarily imply that information about business models and Intellectual Property related to the CitiVerse must always be openly available.
- A CitiVerse platform shall have a trust framework. A CitiVerse platform requires data and services from many different stakeholders. To ensure that these can be trusted, a trust framework shall be in place that provides trustable meta information about stakeholders, data, and services.

³⁹ ANNEXES to the Proposal for a Regulation of the European Parliament and of the Council

Laying Down Harmonised Rules on Artificial Intelligence (Artificial Intelligence Act) and Amending Certain Union Legislative Acts (COM(2021) 206 final).

- A CitiVerse platform shall have a logging mechanism, which enables traceability and auditability.

SECURITY

Scope and references

This section established requirements that enable security and safety amongst different digital systems, platforms, and services supporting CitiVerse use-cases. The goal is to create a safe environment for users and facilitate trust between the platform and digital citizens utilizing the space.

Requirements

Decentralized platforms, adopted by CitiVerse, shall be especially cautious of the following:

- **Smart contract vulnerabilities:** decentralized CitiVerses rely on smart contracts to govern the interactions between users and the virtual world. These smart contracts can be vulnerable to bugs and exploits that can be exploited by malicious actors to steal user funds or execute unauthorized transactions.
- **User data privacy:** decentralized CitiVerses require users to create and manage their own digital identities. However, this data can be vulnerable to theft if the underlying blockchain is not designed with strong protections.
- **Centralized points of failure:** while decentralized CitiVerses are designed to be distributed, there are still certain centralized points of failure that can be targeted by hackers, i.e., centralized servers to handle certain functions, such as identity verification.
- **Malicious actors:** Like any online community, decentralized CitiVerses are vulnerable to malicious actors. These individuals can use various tactics, such as phishing, social engineering, micro-aggression, harassment, misinformation, identity theft, and other societal risks to trick users into sharing sensitive information.
- **Lack of regulation:** Decentralized CitiVerses operate outside the traditional regulatory frameworks. While this can offer greater freedom, it also creates a regulatory vacuum that can be exploited.

PRIVACY

Scope and references⁴⁰

This section provides requirements for the design of CitiVerse interfaces that ensure user privacy and security by implementing robust measures to protect user data, preventing unauthorized access or misuse, and mitigating potential risks associated with interactive experiences in the CitiVerse.

Requirements

Among others,

- CitiVerse interfaces shall avoid deceptive patterns (also called dark patterns) to trap or trick consumers into subscription services against users' best interests and in favour of the application owners' interests, regarding the processing of users' personal data.
- CitiVerse applications shall effectively ensure the possibility for users to easily move their personal and nonpersonal data between different digital services in line with portability rights.

OPENNESS

Scope and references⁴¹

The design of the CitiVerse promotes transparency and accessibility in the exchange of data, information, ideas, and resources. In pursuit of universal functionality and interoperability, a CitiVerse framework founded on blockchain technology and open standards could begin to take shape, with governance resting in the hands of users through decentralized autonomous organizations. This

⁴⁰ European Data Protection Board (EDPB). Requirements 03/2022 on Deceptive Design Patterns in Social Media Platform Interfaces: How to Recognise and Avoid them. [https://edpb.europa.eu/system/files/2023-02/edpb_03-2022_requirements_on_deceptive_design_patterns_in_social_media_platform_interfaces_v2_en_0.pdf]. Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation) [2016] OJ L 119/1. European Declaration on Digital Rights and Principles. [2023]. [European Commission]. [<https://digital-strategy.ec.europa.eu/en/library/european-declaration-digital-rights-and-principles>].

⁴¹ Directive (EU) 2019/1024 of the European Parliament and of the Council of 20 June 2019 on open data and the re-use of public sector information (recast) [<https://eur-lex.europa.eu/eli/dir/2019/1024/oj>]

[https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/733557/EPRS_BRI\(2022\)733557_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/733557/EPRS_BRI(2022)733557_EN.pdf)

decentralized CitiVerse model presents an opportunity to dig in deeper into addressing data protection concerns that often remain unresolved within more centralized business models, as users would have direct control over their data and its sharing permissions.

Requirements

Among others,

- CitiVerse applications shall enable principles of open access, open licensing, open-source software, open data, and any other relevant forms of openness within the defined scope.
- It is acknowledged that there may be legitimate reasons for limited access or restrictions in certain circumstances, such as privacy, security, or intellectual property concerns. However, any limitations should be carefully justified and balanced with the overarching goal of promoting openness.

INTERACTIVITY AND IMMERSIVENESS

Scope and references⁴²

The CitiVerse needs to cater for seamless and immersive interactivity within the virtual hybrid environment by making most of advanced technologies such as virtual reality, extended reality, and haptic feedback⁴³. The aim is to enhance user engagement and experience, promote inclusivity, ensure user safety, encourage the creation and exchange of content and assets, and move between different virtual locations.

Requirements

Among others, the CitiVerse shall:

- Support real-time interaction for user collaboration (including gamification) in the virtual world.
- Offer diverse interaction options (voice, gestures, haptics) for a richer user experience.
- Enable physical navigation within virtual spaces through accurate mapping.
- Foster social connections and community engagement.

⁴² European Declaration on Digital Rights and Principles. [2023]. [European Commission]. [<https://digital-strategy.ec.europa.eu/en/library/european-declaration-digital-rights-and-principles>]

⁴³ [Haptic technology - Wikipedia](#)

- Personalize avatars and virtual environments to match user preferences.
- Provide user control over digital identities, data, and virtual assets.
- Allow users to create, share, and monetize content while respecting rights and rules.
- Promote digital inclusivity through technology distribution.
- Offer new and safe collaborative environments (with shared spaces and multi-user creation).

INTEROPERABILITY

Scope and references⁴⁴

Lack of interoperability leads to fragmented service delivery at local level as well as a lack of communication among different platforms, technologies and stakeholders, resulting in suboptimal services to the public. According to the European Interoperability Framework⁴⁵, several layers are to be considered for interoperability: legal, organizational, semantic (including syntactic aspects), and technical.

Requirements

Among others,

- Legal and organizational interoperability is needed so that platforms supporting the CitiVerse can interact and be interlinked in a seamless and decentralized manner, across different jurisdictions that should not impact their operations.
- On the semantic side, keeping in mind the need to be multi-domains and applications shall be able to access data from different sources (multiple urban data and local digital twin platforms, communities, vertical solutions), which requires agreed data representations, models, and interfaces.
- Interoperability standards are needed to cater for the integration of various technological choices.

⁴⁴ Proposal for a European Interoperability Framework for Smart Cities and Communities EIF4SSCC: <https://op.europa.eu/en/publication-detail/-/publication/f69284c4-eacb-11eb-93a8-01aa75ed71a1/language-en>

⁴⁵ <https://joinup.ec.europa.eu/collection/nifo-national-interoperability-framework-observatory/european-interoperability-framework-detail>

ACCESSIBILITY AND INCLUSION

Scope and references⁴⁶

This section provides requirements to promote inclusive access and equal opportunities for all individuals, regardless of their abilities and geographical location, within the CitiVerse. This section is linked to the sections on interactivity, immersiveness, and inclusion.

Requirements

Among others, the design of CitiVerse environments shall:

- Embrace universal design for diverse users: disabilities, different cultural and social backgrounds, and tech capabilities.
- Tailor features for sensory, cognitive, and physical needs with customization options.
- Integrate assistive tech (screen readers, captions, etc.) for full user participation.
- Accommodate vision and hearing impairments with options like contrast, font size, and captions.
- Simplify for cognitive disabilities and inclusive communication: use clear language and consistent interfaces like text and voice-based interactions.
- Address digital equity through training to prevent exclusion due to tech advancements.

SUSTAINABILITY

Scope

CitiVerse implementation requires to think about environmental sustainability.

Requirements

The design of a sustainable CitiVerse environment shall at a minimum:

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1. ⁴⁶ European Declaration on Digital Rights and Principles. [2023]. [European Commission]. [<https://digital-strategy.ec.europa.eu/en/library/european-declaration-digital-rights-and-principles>]
 2. FG-MV-WG8-I-TG-design-002 - TG-Sustainable CitiVerse Design SMD (WG8), International Telecommunication Union

- Align with human values, principles of ethics and responsible design according to a tech-responsible design approach⁴⁷.
- Be aware of social and economic sustainability needs and impacts in the short and long-term.
- Maximize recycle and reuse to drive design decisions related to the hardware, software, datasets, networking and infrastructure.
- Find a balance between achieving optimal model performance and allocating resources, considering aspects such as data volume and computational power.
- Use solutions to generate energy-efficient virtual environments (e.g., lightweight assets).

USER'S ACCEPTANCE⁴⁸ AND VALUE⁴⁹S

Scope and references⁵⁰

This section provides basic requirements for the use of value-sensitive design to ensure the explicit and transparent articulation of user values and to allow designing for shared public values and social acceptance of the CitiVerse. Users include both individuals and organizations. The use of value-sensitive design helps address intangibles, such as, for example, norms, beliefs, and ideologies.

Requirements

Designers and developers of CitiVerse applications shall:

⁴⁷ D. Tulone. *Tech-responsible Design for AI Systems to Accelerate UN SDGs while Mitigating Risks*. International Conference on Sustainable Development, Track Digital Era, 18-20 September 2023.

⁴⁸ **Acceptance** [Taebi, B. (2017). Bridging the gap between social acceptance and ethical acceptability. *Risk Analysis*,37(10), 1817–1827]: “the fact that a new technology is accepted—or merely tolerated—by a community”.

⁴⁹ **Value** [Friedman, B., Kahn, P. H., Borning, A., & Hultgren, A. (2013). *Value sensitive design and information systems (early engagement and new technologies: Opening up the laboratory*. Dordrecht: Springer]: ‘what a person or group of people consider important in life’. **Value-sensitive design** [B. Friedman, D. G. Hendry and A. Borning. *A Survey of Value Sensitive Design Methods*. *Foundations and Trends in Human-Computer Interaction*, vol. 11, no. 23, pp. 63–125, 2017: a theoretically grounded approach to the design of technology that accounts for human values in a principled and systematic manner throughout the design process.

⁵⁰ European Declaration on Digital Rights and Principles. [2023]. [European Commission]. [<https://digital-strategy.ec.europa.eu/en/library/european-declaration-digital-rights-and-principles>]

- understand the relative importance of different values from stakeholders' perspectives prior to and during the development and implementation of applications.
- be explicit, transparent, and systematic about the values included in development and implementation.
- ensure that the included values represent main social and ethical consideration.
- be explicit and transparent about the choices and trade-offs between conflicting values, as the relative relevance of values gives rise to various societal and methodological challenges.
- increase the social acceptance of the CitiVerse by meeting both the functional and end users' moral and social values.

GOVERNANCE

Scope and references⁵¹

A decentralised governance structure implies distributed self-governance by which decision-making power is distributed across multiple entities or individuals. Decentralised governance often emphasises user empowerment, giving individuals more control over their digital identities and data the CitiVerse. It also allows for greater resilience and flexibility, as decision-making is distributed and not dependent on a single authority. It aims to facilitate innovation, encourage interoperability, and balance the interests of all stakeholders, including businesses, public sector, and citizens, among the others.

Term defined here:

Governance refers to the systems, rules, and structures that manage and regulate activities within the CitiVerse. It establishes frameworks to ensure ethical, legal, and secure use of the virtual space.

Requirements

CitiVerse governance shall be cautious of the following:

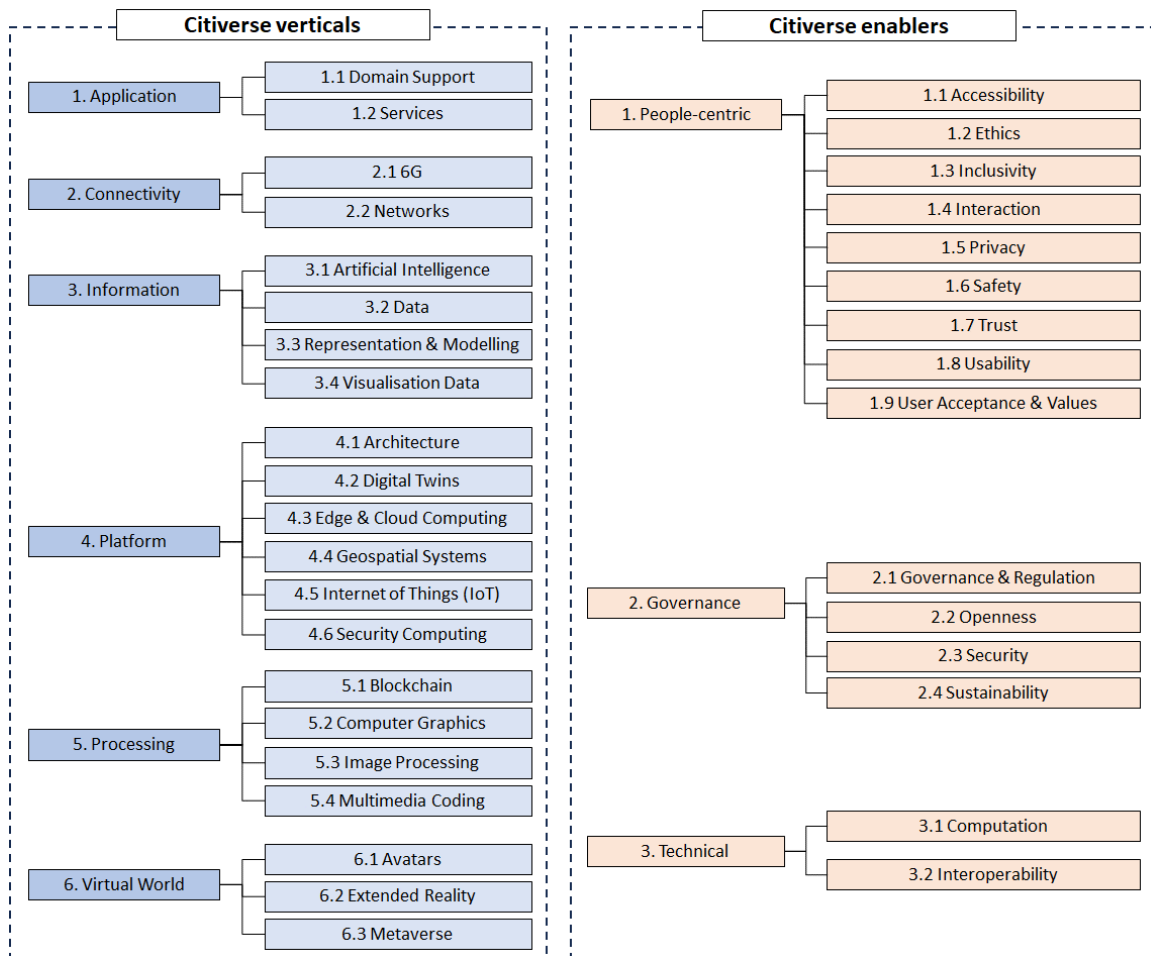
- Decentralized platform: The CitiVerse shall rely on distributed networks, blockchain technology, and consensus mechanisms.

⁵¹ **Governance** [European Parliament's Science and Technology Options Assessment (*STOA*) (2022)]: Governing data and artificial intelligence for all: Models for sustainable and just data governance]: offers a framework and regulation for participation by different actors, it allows for negotiations between competing authorities by providing policies and procedures and provides ways in which conflicts can be mediated.

- Stakeholder representation: the governance structure of a decentralized CitiVerse platform shall strive to include representatives from various stakeholder groups, such as citizens, developers, content creators, businesses, public sector, and civic society organizations, academia, among the others.
- User empowerments: the CitiVerse shall provide them with control over their digital identities, assets, and experiences.
- Multi-stakeholder governance: the CitiVerse shall involve citizens, developers, and stakeholders, such as public authorities, in the decision-making processes related to its development, policies, rules, and control.
- Transparent and participatory governance models shall be established to ensure collective representation and accountability.
- The role of relevant private actors and their relationships with the public sector: effective legal instruments shall be provided to assure that the protection of fundamental rights prevails over business interests of particular actors.

FINDINGS OF THE LANDSCAPE REPORT OF STANDARDS

StandICT has produced a report on a [landscape of relevant CitiVerse standards](#) that include more than 350 references, based on the categorisation showed in the figure below.



Some categories have many references, e.g., geospatial systems (85 references), representation & modelling (67 references), data (65 references), security (61 references), trust (53 references), blockchain (51 references), extended reality (48 references), and interoperability (47 references). While this can be due to the inclusion of entries of lesser relevance, there could be a need in the future to further refine these categories. Some categories lack references e.g., 6G (3 references), edge & cloud computing (3 references), inclusivity (2 references), networks (2 references), openness (1 reference), safety (2 references), sustainability (1 reference), and usability (2 references). This can be due to misses, but it can also be evidence that there is a gap at the standardization level.

Some recent research papers provide as well as technology landscape and identify challenges:

- a taxonomy of the CitiVerse⁵²,
- a survey on security and privacy in the CitiVerse⁵³,
- the integration of AI in the CitiVerse⁵⁴,
- the integration of the edge in the CitiVerse⁵⁵,
- semantic communication in the CitiVerse⁵⁶,
- semantic communication at the edge⁵⁷.

The figure below shows one example on how technology and standards have to be integrated to support the CitiVerse. Taking the viewpoint of JTC 1/SC 24, we need to integrate the following:

- consumer concerns on privacy (PC317), transversal concerns on cybersecurity and privacy (JTC 1/SC 27), societal concerns on trustworthiness (JTC 1/WG 13);
- architecture and system concerns at the software and system engineering level (JTC 1/SC 7), at the IoT and digital twin level (JTC 1/SC 41), and at the AI level (JTC 1/SC 42);
- conformance concerns (CASCO); and
- ecosystem concerns in smart cities (JTC 1/WG 11).

⁵² S.-M. Park and Y.-G. Kim, "A CitiVerse: Taxonomy, components, applications, and open challenges," *IEEE Access*, vol. 10, pp. 4209–4251, Jan. 2022.

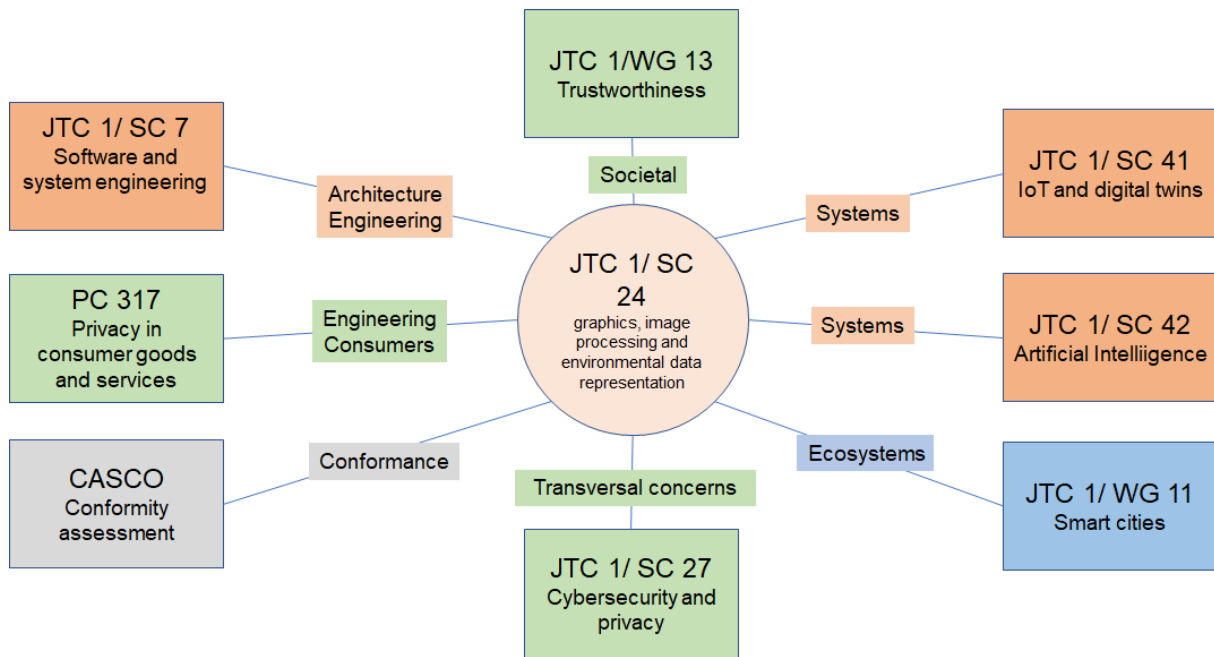
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The main challenge are: integration challenge, technology bricks, organisation in ecosystems, standards structures, and standardisation process.

Identified challenges

There are challenges called for in research papers, as well as identified during a JTC 1/SC 27/WG 5 workshop on the privacy of CitiVerse.

The research challenges are the following:

- R1: Security empowered CitiVerse including and scaling of Identification management, anonymization and pseudonymization to the granularity of the CitiVerse.
- R2: Address the privacy threat of pervasive monitoring by everyone.
- R3: Cloud-edge-end orchestrated secure CitiVerse.
- R4: Cross-chain interoperable and regulatory CitiVerse.
- R5: Energy-efficient and green CitiVerse.
- R6: Content-centric and human-centric CitiVerse.

The integration challenges are the following:

- Ra: guidance on how to integrate technologies.
- Rb: guidance on how to integrate organisations in a CitiVerse ecosystem.
- Rc: guidance on how to match standards to the technologies and organisations.
- Rd: guidance on how to implement a standardisation process.

ROADMAP PROPOSAL ELEMENTS

The EU already boasts a robust ethical and legal framework poised to serve as the foundation of a responsible and open CitiVerse. The first set policy recommendation involves establishing and **promoting standardized technical**

Establishing an open, inclusive and sustainable CitiVerse for all EU citizens involves addressing key challenges and implementing corresponding policy measures by public institutions.

frameworks for the CitiVerse. The second is to work on the integration of evolving technology around **identified use cases**. Smart cities must acquire technologies that prioritize citizen-centric virtual services. Businesses and technology developers drive the development of advanced technologies such as augmented and virtual reality and continuous innovation, ensuring that virtual environments offer engaging and realistic experiences. This commitment to **cutting-edge solutions** is the third priority if we were to contribute to a CitiVerse that captivates users and provides them with an immersive digital space that goes beyond traditional online interactions.

The establishment of a healthy European ecosystem for innovative technologies and suppliers in the short-term (2024-25) is essential and it should be anchored on the following additional recommendations:

- To enhance trust and usefulness of cities' services effectively, **local practitioners and urban planners** must collaborate closely with the supply side. It is also paramount to ensure the participation of **different organisations and population groups** in the CitiVerse development process. This collaboration should focus on identifying ways these technologies can best serve citizens and incorporating evidence-based decision-making into their processes. This can involve incentives for developers to create diverse and accessible content and ensuring that virtual spaces are designed to accommodate users with different cultural backgrounds, abilities, and preferences.
- **Public entities and private technology providers** are to seek strong collaboration, fostering a synergistic partnership to drive innovation and address the unique challenges of smart city and CitiVerse implementations.
- **Local authorities** should collaboratively guide the development of mature and interoperable specifications for the CitiVerse in partnership with technology providers. In doing so, they should encourage developers to prioritize features that enhance seamless navigation and interaction, thereby cultivating an inclusive environment that caters to the diverse needs of every citizen.

- **Policymakers** should also collaborate with industry stakeholders to create guidelines addressing issues like intellectual property, digital identity, and virtual economy regulation. This includes defining the legal status of virtual assets, determining liability in case of disputes, and safeguarding users against fraud. Additionally, **regulatory bodies** should stay abreast of technological advancements to adapt policies accordingly, ensuring that legal frameworks remain effective and adaptable to the evolving nature of the CitiVerse.
- **The supply side** must address a range of challenges, including governance and policy issues, environmental considerations, economic factors, and technical hurdles. This effort aims to establish decentralized, technology-agnostic, trustworthy, secure, open, citizens-centric, sustainable, interoperable, and accessible platforms for Digital Twins and CitiVerse implementations. Finally, these platforms should align with the values, principles, and fundamental rights of the EU.
- **Standardization organizations** must intensify their efforts to systematically address the challenges identified in the landscape analysis findings. It is crucial to foster close coordination with local authorities, ensuring that European and International Standardization organizations play a pivotal role in developing robust standards for the CitiVerse. These standards should enjoy widespread adoption and be grounded in mature, interoperable specifications originating from both the demand and supply sides.
- Finally, by participating in digital communities, acquiring relevant skills, and advocating for ethical practices, **citizens** can also play a crucial role in shaping a CitiVerse that is inclusive, innovative, and aligned with their values. Active citizen engagement contributes to a vibrant and user-friendly virtual environment that benefits everyone involved.

Businesses and technology development companies are instrumental in enhancing the CitiVerse's immersive qualities, intuitiveness, and opportunities for citizens. They should build it keeping in mind the importance of standards, user experience and security,

CONCLUSION

The Living-in.eu community supported by the European Commission, the Committee of the Regions and European networks initiated a reflexion around the development of CitiVerse to unite citizens and bring together EU industries, including SMEs, in enhancing the capabilities of local digital twins. It has taken a proactive step by collaboratively creating a pre-standardization roadmap for an inclusive and sustainable CitiVerse. This effort seeks to define the significance of CitiVerse for citizens and support its deployment, drawing inspiration from smart communities' initiatives in the DIGITAL Europe Programme.

This report underscores the potential of technology to offer a spectrum of experiences, from fully real to entirely virtual but also shows that a comprehensive approach to CitiVerse development requires a combination of technical standards, user protection measures, and experimentation of existing ethical/legal principles into new environments. The transformation of a city or urban area into a mixed reality environment, the "CitiVerse," will be a complex and ongoing endeavour requiring collaboration among urban planners, technologists, policymakers, and content creators.

The report not only discussed definitions and concepts but also identified some specific issues, potential challenges, and blockages for EU cities and communities, emphasizing the need for an innovative and comprehensive strategy to be collectively embraced by its stakeholders. It was prepared by experts and interested practitioners after consulting with Living-in.eu members. It aims at overcoming present and future obstacles and influence future standardization efforts by offering concrete recommendations derived from potential use cases in smart communities.

The authors hope that this effort while marking only the initial phase, will serve as an indispensable stride toward the successful development of an inclusive, citizen-centric, and sustainable CitiVerse within the European Union.

ANNEX I USE CASES

Matrix Development

In order to create a useful matrix allowing to gather, visualise, enrich and generate CitiVerse use cases, the concept was split. On the horizontal axis the urban policy domains were listed, these are based on the smart city domains (Bellini et al., 2022). On the vertical domain the functions possible through a single or combination of CitiVerse technologies were added. The matrix was then tested and simplified through plotting use cases from experts and out of publications. The transition towards Smart Education and the link between Smart Tourism and culture were explicitly added. After simplification, the matrix also proved to be a good basis for adapting commercial use cases to the urban perspective and generating new possibilities.

The filled in matrix can be found below.

		City and Communities Domains									
		Living Area & Infrastructure	Mobility & Transport	Social Policy	Economic and Labour Policy	Environmental Policy	Healthcare & Well-Being	Governance & e-Government	Education & Skills	Culture & Tourism	
Activities possible in the CitiVerse	Designing										
	Simulating										
	Contributing										
	Deciding										
	Operating										
	Collaborating										
	Transacting										
	Socialising										
	Experiencing										
	Communicating										
Learning											

Table 1: Gathered use cases in the matrix accessible at

https://miro.com/app/board/uXjVMpAb6Cs=?share_link_id=458425220124

Use Case Name	Description	Main Domain	Main Activity	Term
3D Collab room	3D rooms for collaboration on urban planning initiatives	Living Area & Infrastructure	Designing	LT
Predict, plan & sign-off	CitiVerse offers a tool to predict demand and become more resource-efficient, visualize construction efforts before final sign-off as well as plan against future disasters.	Living Area & Infrastructure	Designing	MT
Decision argumentation	Community actors are able to understand the impact of decisions taken by the city	Living Area & Infrastructure	Simulating	MT
Alternative urban development	Simulation models can be very useful to propose different alternatives for an urban development. People could participate	Living Area & Infrastructure	Simulating	LT
Urban liveability simulation	Simulating how people can improve living experience thanks to infrastructure	Living Area & Infrastructure	Simulating	LT
Public space gaming	Gaming for good to find solutions for problems in public spaces	Living Area & Infrastructure	Contributing	MT
Online advisory	Advisory on infrastructure	Living Area & Infrastructure	Contributing	ST
Collab choices	Collaborative choices for improvement of public spaces	Living Area & Infrastructure	Deciding	ST
Online developments	Developments in real-world projects based on specifications and conditions approved in the digital world	Living Area & Infrastructure	Deciding	MT
Refurbishments prio.	Experimenting with digital twins for public buildings in order to prioritize refurbishments.	Living Area & Infrastructure	Deciding	MT
Public works	Public works	Living Area & Infrastructure	Operating	(unclear)
Remote assistance	Provide remote assistance in remote or rural areas	Living Area & Infrastructure	Operating	LT
Physical Multi-usage	Optimal multi-usage of physical space	Living Area & Infrastructure	Collaborating	MT
Participation	Participation models through CitiVerse	Living Area & Infrastructure	Collaborating	ST
Awareness	Raise-awareness campaigns	Living Area & Infrastructure	Communicating	ST
Traffic sim	Virtual worlds can help optimise traffic flows based on real-time simulations	Mobility & Transport	Simulating	MT
Traffic simulation	Simulate traffic patterns	Mobility & Transport	Simulating	MT

Gridlock solving	Gridlocks can be predicted and traffic can be diverted before a problem escalates	Mobility & Transport	Simulating	LT
Living & Moving	Sustainable mobility show how people are living and moving	Mobility & Transport	Simulating	MT
Living lab	Test and engage on new adaptation to the urban environment	Living Area & Infrastructure	Contributing	ST
Digital objects	Gather feedback or contributions in the physical world through digital objects	Mobility & Transport	Contributing	ST
Game 4 good	Gaming for good to gather data	Mobility & Transport	Contributing	ST
Travel Prep	Preparing travel	Mobility & Transport	Deciding	ST
Situational awareness	Real time situational awareness	Mobility & Transport	Operating	ST
Traffic control	Traffic control rooms could evolve to a more realistic approach	Mobility & Transport	Operating	LT
Virtual exchanges	Diminish the impact of travel by enabling virtual exchanges	Mobility & Transport	Socialising	ST
Awareness campaigns	Raise-awareness campaigns	Mobility & Transport	Communicating	ST
New mobility models	Allow students and researchers to identify mobility problems and study, develop and simulate new mobility models	Mobility & Transport	Learning	MT
Collaboration	Collaborating on a project	Social policy	Collaborating	MT
Interaction	New forms of interaction and collaboration among people	Social policy	Collaborating	ST
Community support	community support and social help services	Social policy	Collaborating	MT
Community life	Community life	Social policy	Socialising	ST
Social reality	Find information on the social reality	Social policy	Learning	MT
Prep Citizens	Prepare citizens, utilizing for change management and cultural transformation	Social policy	Learning	ST
Attract Residents	Attracting new residents – they can walk around their new neighbourhood. Embedded in real-estate websites	Economic & Labour policy	Deciding	ST
Circularity	Circular economy use cases to manage circular value chains	Economic & Labour policy	Operating	MT
Shopping	Shopping	Economic & Labour policy	Transacting	ST

Creating employment	Creating employment	Economic & Labour policy	Transacting	MT
International contributions	Allow international talent to contribute	Economic & Labour policy	Transacting	ST
Material use	Decrease the waste of materials engaged in production	Economic & Labour policy	Transacting	LT
Awareness campaigns	Raise-awareness campaigns	Economic & Labour policy	Communicating	ST
Economic reality	Find information on the economic reality	Economic & Labour policy	Learning	ST
Natural resources	Optimise natural resource allocation	Environmental policy	Simulating	MT
Energy simulation	Simulate energy demands in various situations	Environmental policy	Simulating	MT
Flood simulation	Simulate urban floods	Environmental policy	Simulating	MT
Climate simulation	Simulate climate change	Environmental policy	Simulating	MT
Heat islands	Urban heat islands using several sources of data and models.	Environmental policy	Simulating	MT
Real-time policy	Evidence-based policy in real time supported by emergency simulation tools	Environmental policy	Deciding	LT
Green twin	Green Twin use case encompasses applications that monitor and coordinate systems' operation and people's activities to reduce energy consumption to help tackle climate change challenges while enhancing people quality of life.	Environmental policy	Operating	MT
Raise awareness	Raise-awareness campaigns	Environmental policy	Communicating	ST
Issue gaming	Gaming for good to place attention on issues	Environmental policy	Communicating	MT
Life support	Predict, prepare and provide for the needs of citizens across their different life phases including healthcare and sustainable mobility.	Healthcare & Well-Being	Designing	LT
Well-being	For good economy of smart cities, human health is a priority, which is beginning to be looked at comprehensively. Healthcare of a person includes the well-being of both body and mind.	Healthcare & Well-Being	Designing	LT

Monitor health	Enable citizens to make use of applications to monitor or improve on own or dependants health	Healthcare & Well-Being	Contributing	MT
Body implants	Define and enforce ethical rules and social norms for body implants to promote health, safety and privacy	Healthcare & Well-Being	Contributing	(unclear)
Public virtual safety	Public virtual safety	Healthcare & Well-Being	Operating	MT
Peer support	Enabling peer support (e.g. support groups)	Healthcare & Well-Being	Collaborating	ST
Nudging governance	Pilot creative governing and public services models that use insurance, procurement and tax as incentives for nudging citizens, companies and the city towards inclusive, sustainable and healthier choices	Healthcare & Well-Being	Transacting	MT
Health services	Better health services	Healthcare & Well-Being	Transacting	LT
Strategic foresight	Strategic foresight: Safely simulate inefficient or dangerous situations in a city-wide context and implement changes proactively	Governance & e-Government	Designing	MT
Digital twins with inhabitants & processes	People-centric governance mechanisms made possible through fully- featured digital twins of inhabitants, objects and processes.	Governance & e-Government	Designing	LT
Policy scenarios	Simulate policy scenarios (economic and political)	Governance & e-Government	Simulating	MT
Simulation & predictive services	City policy makers and managers use and apply simulation and predictive services to support decision making in key areas	Governance & e-Government	Simulating	MT
Mitigate risks	Mitigate potential risks	Governance & e-Government	Simulating	MT
Optimize resources	Optimize financial and human resource allocation	Governance & e-Government	Simulating	MT
Citizen engagement	Citizen engagement	Governance & e-Government	Contributing	MT
City efficiency	Actions to improve efficiency in the running and management of the city	Governance & e-Government	Contributing	(unclear)
Process advisory	Advisory on processes	Governance & e-Government	Contributing	MT
Engagement	Virtual worlds can enhance democratic participation by offering new possibilities for people to voice their ideas, opinions and concerns in more engaging ways	Governance & e-Government	Contributing	ST

Public spending	Choices for public spending	Governance & e-Government	Deciding	MT
Public services distribution	Public services distribution	Governance & e-Government	Operating	(unclear)
Efficiently governing	Governing cities more efficiently	Governance & e-Government	Operating	(unclear)
Virtually abled	Enable citizens to be included despite being “other” abled (cognitively, emotionally or physically)	Governance & e-Government	Collaborating	MT
Official interaction	Interact with public officials	Governance & e-Government	Collaborating	ST
Cost-effectiveness	Improve service delivery usability, scalability and cost-effectiveness	Governance & e-Government	Collaborating	(unclear)
Virtual interaction	Virtual interaction with administrative services to find information	Governance & e-Government	Transacting	ST
Personalised services	Public services engage with people for more personalised administrative services	Governance & e-Government	Transacting	ST
Citizen's interaction	Virtual worlds provide access to essential amenities and promoting remote and virtual experiences, enabling citizens to interact and collaborate with one another, while minimizing the need for physical travel.	Governance & e-Government	Transacting	ST
Service requests	Request services following administrative procedures	Governance & e-Government	Communicating	ST
15 min city	CitiVerse will enable citizens to directly involve themselves in their cities via an immediate radius. The concept of the “15-minute city” feeds into smart city discourse, whereby citizens have access to all essential services all within a 15-minute walk or bike ride. The purpose here is to reduce the need for a car. With CitiVerse, services that may have required the use of travel, i.e., engaging with a local authority, GP, etc, can now be conducted via CitiVerse.	Governance & e-Government	Communicating	ST
Study problems	Enable citizens to study specific phenomena	Governance & e-Government	Learning	MT
Playful city	Kids playing with city planning Lego/Minecraft-style	Education & Skills	Deciding	ST
Scientific simulations	Schools can provide immersive learning environments where	Education & Skills	Simulating	LT

	students can explore and make scientific simulations			
Real-life training	Training citizens and employees in real-life conditions in preparation of impactful emergencies	Education & Skills	Simulating	LT
Digital humans	The use of digital humans to help enable 24/7 support in virtual worlds. Interactive, artificial-intelligence-driven representations that exhibit some of the characteristics, personality, knowledge, and mindset of a human. For instance, the ability to speak to a digital human GP to help triage medical assistance or speaking to a digital human to dispute a parking ticket.	Education & Skills	Deciding	LT
Immersive education	Immersive education actions	Education & Skills	Operating	ST
Serious games	Serious games	Education & Skills	Collaborating	ST
E-education	Following education	Education & Skills	Learning	ST
Campus digital twins	Universities can create campus digital twins	Education & Skills	Learning	MT
Historic worlds	Immersive learning environments where students can explore virtual worlds, historical settings	Education & Skills	Learning	ST
Talent platform	AI-driven talent platform (identifying gaps and opportunities and matches students, seekers and businesses through personalized and targeted upskilling	Education & Skills	Learning	MT
Edu-gaging	More engaging education and training	Education & Skills	Learning	MT
3D art	Cultural enrichment of spaces through 3D art	Culture & Tourism	Designing	ST
Virtual tourism	Virtual Tourism	Culture & Tourism	Simulating	ST
Save heritage	Safeguard of cultural heritage	Culture & Tourism	Contributing	ST
Preservation & reconstruction support	Digital twins can support the preservation or reconstruction of cultural heritage buildings ex. Notre Dame Cathedral in Paris	Culture & Tourism	Contributing	ST
Virtual tourism	Make culture events & products more accessible for citizens & tourists	Culture & Tourism	Socialising	ST

Riga Song Festival	Best Practice: Riga city creating new product to make national song festival (UNESCO heritage) accessible for everyone on Mežaparks grad stage	Culture & Tourism	Socialising	Existing
Virtual activities	Participating in touristic activities	Culture & Tourism	Experiencing	ST
Virtual heritage	Discover cultural heritage	Culture & Tourism	Experiencing	ST
Virtual landmark	Discover main landmarks	Culture & Tourism	Experiencing	ST
Virtual Acropolis	Best Practice: Virtual tour of Greek capital (Acropolis)	Culture & Tourism	Experiencing	Existing
3D Dracula castle	Best Practice: 3D Virtual tour of Dracula's castle	Culture & Tourism	Experiencing	Existing
Place de Versailles	Best Practice: Place de Versailles in France	Culture & Tourism	Experiencing	Existing
UnderwaterMuseum	Best Practice: UnderwaterMuseum (ERDF, Museum of Kastela)	Culture & Tourism	Experiencing	Existing
Virtual tourism	Diminish the impact of travel by enabling virtual visits	Culture & Tourism	Experiencing	ST
Immersive cultural experience	Immersive cultural experiences	Culture & Tourism	Experiencing	ST
Virtual guide	The use of CitiVerse to transport citizens/tourists to virtual worlds/digital twins of cities as well as bringing the digital to the physical world, i.e., AR/VR/MR glasses that can help guide people around cultural sites, providing information as an overlay, etc.	Culture & Tourism	Experiencing	ST
VR tours	VR tours to promote the cultural and natural EU heritage	Culture & Tourism	Experiencing	ST
Entertaining	Entertaining others	Culture & Tourism	Communicating	ST
Citizen's discovery	Citizen's discovery: Find out major events taking place	Culture & Tourism	Communicating	ST
Historic immersions	Historic immersions to understand urban change	Culture & Tourism	Learning	MT

Table 2: Exhaustive use cases with capabilities per domains

Priority Use Cases

On the 4th of September a CitiVerse workshop was held within the Living-in.eu technical subgroup. After a short introduction of the objectives, the concept, and an explanation of the matrix a series of exercises was done. The participants were asked to review the matrix and add any missing use cases. After completion they proceeded to vote on the use cases based on the needs and priorities in cities and communities.

The figure showing the distribution of the votes gathered can be found below.



Use Case	City Communities & Communities Domain	CitiVerse Activities	Votes
Urban heat islands using several sources of data and models.	Environmental Policy	Simulating	8

Public virtual safety	Healthcare & Well-Being	Operating	7
Simulate urban floods	Environmental Policy	Simulating	7
Traffic control rooms could evolve to a more realistic approach	Mobility & Transport	Operating	7
Evidence-based policy in real time supported by emergency simulation tools	Environmental Policy	Deciding	6
Simulate energy demands in various situations	Environmental Policy	Simulating	6
Simulate traffic patterns	Mobility & Transport	Simulating	6
Simulate climate change	Environmental Policy	Simulating	5
Simulation models can be very useful to propose different alternatives for urban development. People could participate.	Living Area & Infrastructure	Simulating	5
Training citizens and employees in real-life conditions in preparation of impactful emergencies	Education & Skills	Simulating	5

Table 3: Votes per use case

Based on total votes per individual use case, priority was given to complex cases mainly focusing on simulations. The following table states the top 10 cases. In addition to the individual use case votes, a tabulation was made to compare the prioritization in function of needs according to CitiVerse activities or domains. The table below shows the top 6 results for each.

Function (Vertical axis)	Total votes	Domain (Horizontal axis)	Total votes
Simulating	69	Environmental Policy	39
Operating	30	Mobility & Transport	36
Deciding	20	Living Area & Infrastructure	31
Contributing	17	Governance & e-government	26
Designing	17	Culture & Tourism	19
Experiencing	8	Education & Skills	18

A series of criteria composing of the availability of data, the integration complexity and the needed change to implement were also taken into account by a group of experts to come up with the following prioritization of use cases.

Prioritized Use Cases Proposition

Quick-Wins

Virtual tourism
 Real-time situational awareness
 Gather feedback through virtual objects

Middle-term

Urban heat islands
 Public virtual safety
 (Show) Simulate urban floods, traffic patterns... (ldt)
 Engage on adaptations to urban env.

Longer-term

Traffic control rooms
 Evidence-based policy in real time (emergency services)
 Emergency training citizens

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