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Master Thesis

The impact of virtual cities on urban planning

in the case of social interaction and participatory democracy

by

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Abstract

Understanding, simulating, and forecasting the future of cities in the virtual world are necessary for controlling and analysing the effect of **virtual cities** on the **real world.** Cities, where the global population is gathering and providing a physical environment for citizens, are becoming the locus **of virtual, networked-based economic, political**, and **cultural activities**. Thus, digital cities will represent a new manifestation of this phenomenon. Moreover, **virtual reality systems** give experts visual access to digital information about this environment through initiatives to digitally model and simulate the real environment, users, and services. **Virtual models** can be used to democratize planning, evaluate many future scenarios, understand how the built environment operates, and train emergency response, maintenance, and operations employees across scales, from buildings and neighbourhoods to infrastructure and cities. However, besides the use of virtual cities in various aspects of urban design, we can use them as a tool for **participatory** and **social interaction** in building **democratic** communities.

The purpose of this research is to analyse what virtual reality is and how it can change the experience of urban planning. It investigates the definition of virtual cities and compares their effects and uses for planning in the real world. Since cities without citizens are without meaning or function, it also explores the explanation of digital society, social interaction, and the user experience in the virtual environment.

Additionally, it explores the usage of virtual cities as a tool for participation and how they affect the existence of democratic cities. By studying the history, cases, and future of this technology, we can have a better outline of this issue and build practical and better cities in the future.

KEYWORDS: Virtual city, digital twin, virtual reality, city model, urban planning, decision making, digital citizen, social interaction, participation processes, democratic design.

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Chapter 1: Introduction

We live in a world of **cities**, where more than half of the world's population lives and works in cities, whether dense or sprawling, metropolitan or networked, expanding, or contracting. In the urban age, the city plays a significant function as a habitat, not only as a development growth machine and a driver of community evolution and vitality, but also as a generator of innovative lifestyles, more sustainable, smart, creative, and as a reformer of its development pattern. (Carta 2014)

Modern information and communication technologies are rapidly eroding the boundaries between the workplace and everyday life. As a result, new research fields emerge, such as **digital cities** research, that focus on the design, evaluation, and consequences of ICT-based systems for social and urban life. (Ishida 2000)

Despite the similar language, digital cities include a variety of aims, services, system architectures, organizational forms, and economic models. This diversity stems from the **various social environments** in which digital cities have grown. At the same time, digital cities are a dynamic phenomenon, and it is expected that as computer and network technology advance, as well as the social and economic environment in which they function, digital cities will evolve. (Ishida 2000)

But how can virtual reality be applied to the management, creation, and building of the built environment, architecture, and urban design?

The relationship between urbanism and the use of virtual reality is the primary focus of this review essay. The paper will begin with background information on virtual reality, augmented reality, various devices, and their history of it. We will study the virtual environment and the usage of the digital twin in urban planning.

Moreover**, Architecture** is the manifestation of **civilization** as a significant place, whether it be physical or digital. Both physical and virtual architecture employs an architectural organization to organize forms and spaces in the environment, while each has its own set of limitations and context. (Campbell 2003) However, **Virtual Reality systems** give experts visual access to digital information about this environment through initiatives to digitally model and simulate the real environment, users, and services. Virtual models can be used to **democratize planning**, evaluate many future scenarios, understand how the built environment operates, and train emergency response, maintenance, and operations employees across scales, from buildings and neighbourhoods to infrastructure and cities.

For collaborative and **participatory processes** (PP), with a focus on planning and decision assistance, we can create a **digital twin** that can be deployed and represented seamlessly across all scales, on many layers, and in diverse categories of data. We employed cooperative virtual Reality settings for all participative procedures. When it comes to participation, VR tools, Digital Twins, and visualization techniques are helpful. It takes genuine power, not hollow rituals, to influence the result of such processes, as Arnstein (1969) points out. Our strategy might provide decision-makers, planners, and people with the tools they need to work together.

This essay focuses on a particular urban initiative: the contribution of so-called virtual cities, or digital cities, to enhancing public participation.

1.1 Methodology

The research methodology for this study has been decided upon as the qualitative research method. The primary aim of this research project is to describe the impact of virtual cities on urban planning, with a focus on social interaction and democratic design. By studying the books, articles, and case studies by covering the main topics like virtual reality systems, virtual environments, digital twins, virtual cities, digital citizens, and democratic participation, I tried to find answers to the main questions of my thesis. By analysing cases, we see the advantages and disadvantages of this system. This way of analysing the background and the reason for their invitation helps us to find a clear future and use this technology to develop the urban planning of our future physical cities to have a more democratic community.

1.2 Thesis aim and structure

The main aim of this research is to explore the impact of virtual cities on urban planning and see the result of that in social interaction and the participation of citizens to have a democratic community.

To answer this and find a scenario of having a virtual city model, we started to research the exact meaning of the virtual systems, their background, and technical preferences. The second chapter explores how virtual reality can shape the user experience, which will shape the following chapters present and discuss virtual environments and their following technologies, like metaverse, digital twin, etc.

In the third chapter, we describe virtual cities and the connection of physical cities with virtual cities, as well as an architectural design theory in virtual environments. By exploring some cases, we can figure out the advantages and disadvantages of this technology besides the development and technical system. Chapter four discusses the user experience and digital citizens of virtual cities. We see how we can shape user experience and develop social interaction in a virtual environment. Also, we explore the answer of a different generation to this system. Finally, in the fifth chapter, we conclude the role of participatory democracy in this environment and see how users can participate in the decision-making of their cities.

1.3 The main questions

What are the impacts of virtual cities on urban planning?

How has the urban planning been operated, designed, and developed using virtual reality?

How will the implementation and bridge between real and virtual cities look?

How do virtual cities help citizens participate in decision-making to have a democratic city?

1.4 Objectives

The following thesis figures out the architectural role in presenting the virtual world and its effects on the real world. This research investigates the functionality, aesthetics, and sustainability of virtual cities.

The main objectives of this study:

- Investigate the concept of virtual environment
- Analyze the effect of virtual cities on real cities
- Compare the psychological effect of virtual cities on generations
- Analyze the history of urban designing and its expectation on virtual cities
- Review digital twin on urban planning
- Study the impact of virtual cities on increasing participatory and their result
- Designing democratic community with virtual cities

Chapter 2: Virtual reality systems

2.1 Introduction to virtual reality systems

Virtual Reality (VR) is a computer-generated environment with scenes and objects that are real, making the user feel they are immersed in their surroundings. Making proper decisions for using VR to achieve real value challenges us with a problem given the quick speed of technological progress in VR systems and digital platforms. In this chapter, we look at a few crucial issues: What are virtual reality systems, and what is their history? Why is that important? How has the built environment and urban planning been operated, designed, and developed using virtual reality? What distinguishes the metaverse from virtual reality? (Whyte and Nikoli 2018)

These questions are significant because the growing use of digital data for decision-making through Building Information Modelling (BIM) and related technologies has rekindled interest in and advanced the usage of virtual reality.

Therefore, a range of virtual, mixed, and augmented reality technologies are being applied to represent the built environment and to make decisions on the operation, design, and construction of new structures and infrastructure. The key to this is well-structured digital data, which consumers may access regardless of location, format, or device as computers become universal. The more methodical use of digital information on buildings and infrastructure, as well as significantly more effective and widely available VR systems and applications across a variety of desktop, laptop, and mobile devices, have replaced the exponential growth in computing power and early experiments with virtual reality (VR) systems in recent decades. (Whyte and Nikoli 2018)

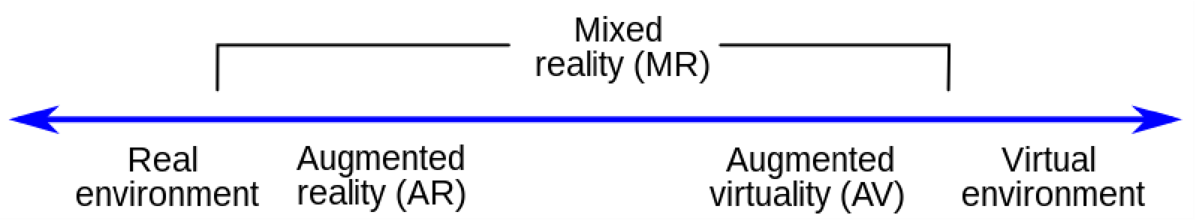
Additionally, consumers and small and medium-sized businesses can now afford immersive visualization applications using head-mounted displays (HMDS) and augmented reality (AR) devices, which can be used to improve current interventions in the built environment and comprehend those that will come. These open new avenues for innovation, and many experts are actively experimenting with these technologies. However, we have also become increasingly aware of how technology advancements frequently outstrip our capacity to properly understand how to utilize their benefits. Our relationship with the built environment is changing because of the expanding use of immersive and augmented visualization techniques, which poses new challenges for professionals working in the fields of planning, architecture, engineering, construction, and operations who want to use VR technology.(Whyte and Nikoli 2018)

Making proper decisions for using VR to achieve real value challenges us with a problem given the quick speed of technological progress in VR systems and digital platforms. But the focus is on bringing experts inside a building information model using immersive virtual reality as well as bringing this model to the job site using augmented reality.

Numerous research has focused on the educational usefulness, knowledge transfer, and learner behaviours of virtual learning environments, which are growing in popularity along with developments in virtual reality technology. Furthermore, despite the lack of specialized models for immersive environments, the concept of user experience is already widely discussed in scientific literature.(Tcha-Tokey et al. 2018a)

2.2 The virtuality continuum

Milgram and Kishino (1994) proposed a continuous virtual concept to better distinguish between several types of virtual reality and augmented reality and to what extent they represent aspects of "virtual" and "real" environments (Figure 1.1). According to this concept, there are two types of mixed reality environments: those that combine real and virtual worlds and those that are made up entirely of real and virtual elements. However, mixed (or hybrid) reality approaches are more frequently referred to as augmented reality, or those that support real environments with virtual information, because this term defines environments that combine both real and virtual objects. Apps for smartphones that overlay virtual directions, store locations, and other information over information about actual locations are examples of augmented reality (AR) applications. (Whyte and Nikoli 2018)



1.1 The virtuality continuum
Source: Adapted from Milgram and Kishino, 1994 (Whyte and Nikoli 2018)

As a result, only the visual aspects of the mixing of the physical and digital worlds are considered in the various sections of the continuum. Sound, smell, haptics, and taste are not included in this continuum.

Four categories make up the virtuality continuum:

- **Real environment:** Contains only actual, physical things. The lower left point on the continuum of virtuality is the real world.
- **Augmented reality:** Digital elements are added to the physical environment.
- **Augmented virtuality:** The addition of actual or physical objects enhances the virtual world.
- **Virtual environment:** Only includes digital items. The ideal end of the virtuality spectrum is the virtual environment. (Skarbez, Smith, and Whitton 2021a)

Contrarily, augmented virtual worlds, a concept mostly used in research contexts, refer to applications in which users primarily view digital information supported by actual contextual data, like that provided by navigational GPS devices. Using examples of diverse usage scenarios, tasks, and user experiences, we frame this discussion on the use of both virtual and augmented reality technologies. Using this method, we can comprehend how virtual and augmented reality apps can alter user perceptions and modify how digital information is understood, which in turn can have an impact on the planning and execution of built-environment projects. To do this, we outline case studies, user experiences, and active research projects to show how augmented and virtual reality are applied in the domains of design, engineering, and construction. (Whyte and Nikoli 2018)

The RV continuum is discontinuous, and complete virtual reality cannot be achieved, as we discovered when re-examining Milgram and Kishino's theories. Second, contrary to widely held belief, typical virtual reality experiences are included in the definition of mixed reality. (Skarbez, Smith, and Whitton 2021b)

2.3 What are Virtual Reality systems?

A computer-generated environment called "virtual reality" (VR) has images and objects that seem real, giving the user the impression that they are surrounded by the environment. An object known as a virtual reality headset or helmet is used to view this environment. Virtual reality (VR) enables us to learn how to conduct heart surgery, totally immerse ourselves in video games as if we were one of the characters and improve the efficacy of sports training to maximum performance.(Iberdrola 2018)

In addition, giving users engaging, naturally interactive, and immersive experiences within a virtual environment are the aim of virtual reality systems. Thanks to input and output devices that are connected to the virtual model, users in a virtual reality environment can enjoy a range of experiences. These systems let users interact with and experience data that is either generated by computers or based on physical reality (actual data). Virtual reality can be thought of as a flexible system that, depending on how VR systems are developed, can be tailored to how we wish to view VR information for a wide range of jobs. The same system component is used by both AR and VR. However, AR enables users to superimpose digital data from a real-world perspective.(Whyte and Nikoli 2018) Moreover, the hardware and software of the VR system in which the model is presented have an impact on how users interact with VR models utilizing input and output devices. (Whyte and Nikoli 2018)

2.3.1 Input and output devices

Configuring input devices for VR and AR, such as control and location tracking, and output devices for visual, auditory, olfactory, tactile, and dynamic systems (Isalde, 1998).

A VR or AR application display adjusts to users' postures and head or body movements as they interact with an environment when an interaction device is coupled with a position tracking system. (Whyte and Nikoli 2018)

Samples:

Olfactory **interfaces**, which are used to experience virtual reality through smell, are even less popular. Due to the chemical structure of the sense of smell, scent-generating sources that are often connected to programs that regulate their release and blending are necessary. Practically speaking, olfactory interfaces in VR are trickier to develop than visual or aural interactions.

Haptic **interfaces** are experienced through touch. For instance, according to Brooks (1999), a sizeable portion of the sense of presence and engagement present in VR car simulators stems from the presence of haptic information because these simulators enable users to "touch" features that are reachable on real automobiles. The employment of data gloves and other force-feedback devices to apply forces and vibrations that enable actual perception is typical of haptic interfaces, which are used in situations when the manual operation of virtual objects is required.

Kinaesthetic interfaces are closely related to the haptic feedback that comes from physical movement. Kinaesthetic feedback is frequently applied to activities involving movement and navigation in virtual environments. For instance, hand-held controllers with six degrees of freedom allow for physical interaction with a virtual environment and may also offer force or tactile feedback. Virtual reality (VR) apps that are the size of a room frequently use physical movement to navigate or "walk through" virtual environments. For instance, the artist Charlotte Davis' 1995 piece "Osmose," in which she created a virtual environment that allowed users to walk across space by breathing (Fieldgate, 2017), challenges conventional beliefs about how people engage with and navigate VR spaces.

A range of senses is also engaged in current VR investigations using various input and output technologies. Using brain wave-detecting headsets, some experimental work investigates how the mind may move through virtual reality worlds.(Whyte and Nikoli 2018)

2.3.2 Development of virtual reality systems

Virtual and augmented reality systems have been smaller, less expensive, and more adaptable over the past few decades thanks to the exponential rise of processing power, which has also increased the sensitivity of input devices and the resolution of output devices. The accessibility of VR systems for users in the built world has expanded because of this rise in computer power, and new application areas have become available. Table 2.2 provides a timeline of significant advancements and notable changes in the delivery of digital projects (Lobo and Whyte, 2017;

Whyte and Levitt, 2011), as well as progressions in information models and standards and the hardware, software, and interfaces used in VR and AR systems for built infrastructure. (Whyte and Nikoli 2018)

Timeline

	Pre 1980	1980-1989	1990-1999	2000-2009	2010-2019	2020
Focus of digital delivery :	Systems dedicated to particular tasks, batchprocessing and real time	Knowledgeformalization; systems that can run more than one application	Share information and knowledge across teams and firms	Agile, decentralized-methods, centeralized data	Integration,collaboration, data centric engineering, cloud based solution	?
Information models and standards:		Lines and vectores	Parametric modelling	Indsutry Foundation Classes (IFCs)		?
Hardware :	Mainframe computer systems	First (desktop) personal computers	Laptops, Internet and first mobile computing	Mobile computing (smart phones, data storage	Glasses, touch screens, sensors, wearbles	?
Software :	Computer graphic techniques	PC-based CAD and project managment; simulation	Visula decision making tools, Internet, shared workspaces, open graphic libraries	Automated digital search, expert systems, project extranets, game engines	Machine learning, platform technologies, diverse operating systems	?
Input and output devices:	Computer mous, scren, haptic glove, light-pen, joystick	Tread-mill; commercial HMD	CAVE, virtual reality desks	3D laser scanning and geometry capture	HMD for AR and VR, CAVE2	?

Figure 2.2 Development of enabling technologies (Whyte and Nikoli 2018)

2.3.3 The future of Virtual Reality

Although there is no way to predict the future, the writer and essayist William Gibson's (1999) adage that "The future is already here; it's just not evenly distributed" is a decent place to start when thinking about the potential of virtual reality in construction projects. We must consider privacy and security concerns as well as the growing technology integration and life-cycle integration, as we become more experienced users of digital technologies. We may envision scenarios where displays could be transmitted directly into a viewer's retina or through customized glasses, as opposed to viewing digital data on a monitor or smartphone. Additionally, we should expect a rise in the convergence of VR and associated technologies that use sensors, BIM, big data, artificial intelligence, and VR in new ways. We might also give these technologies' carbon footprints more consideration. We may look forward to technological advancements such as:

- More integration of VR with BIM
- More wearable and auto-stereoscopic devices
- More data capture and video
- More sensory-rich applications
- New platforms that support a range of uses and applications
- Distributed virtual environments, and teleoperations

Regarding the application of such VR technology, we also have a lot of options. Digital technologies, for instance, might improve our understanding of the interactions between the built and natural environments, giving us a wider perspective of the physical world. Alternatively, the built environment itself might become more cyber-physical in nature, further isolating us from our physical surroundings.(Whyte and Nikoli 2018)

2.4 Virtual environment

We inhabit a larger universe where real and virtual spaces interact and affect both our real and virtual lives. The world of communication, which is currently dominated by image culture, is transitioning into the world of interaction in a society that is increasingly reliant on technology. Multi-user virtual environments (MUVEs), particularly Second Life (SL), are virtual worlds where users can construct three-dimensional environments and items, move around them using avatars, and interact with other users in real time.(Moneta 2020)

2.5 Changing experiences in the urban planning

As was previously discussed, digital means of engagement have grown more complex and widespread. Smartphones and social media are used to mediate various forms of engagement around the world, and for many of us, utilizing this technology makes it more difficult to preserve the separation between our personal and work lives. Friends' updates can be viewed in the office, while emails can be read at home. Even though incorporating history into a virtual world might seem absurd, all these factors are crucial to the design process. Our experiences and the degree, pattern, and pace of our contact with the built and natural environments in which we function are reflected in and shaped by these changes in the way we utilize digital technology. (Whyte and Nikoli 2018)

Fundamentally, the tools we employ to visualize the built environment are like those we employ to perceive, comprehend, and construct it. To inform how we use VR systems to design, create, and manage built-environment projects. It is essential to explore relationships between digitally mediated visualization and our perceptions. (Whyte and Nikoli 2018)

To "read" a virtual world as a representation of a built-in or natural environment, users also require a certain level of visual and digital literacy. In the past, substantial advancements in display technology have occurred at the same time as fundamental shifts in how people perceive the world. (Whyte and Nikoli 2018)

Many media, including movies, television, automobile windshields, computer monitors, and video game consoles, have started to show the world dynamically in the 20th century, allowing us to realize for the first time how our perspective is encroaching on the outside world while we are still. These experiences served as the foundation for our creation and use of VR systems years later. Because these phenomena are not observed in our physical perception of the real world, VR applications frequently employ the language of slices, panels, and zooms that they must learn, just like movies, animation, and television media. Our perceptions are frequently reduced to a dynamic vision through a framework in which our vision varies, much like while driving a car. Our bodies are still concerned with their environment, nevertheless. This research's main objective is to consider how virtual experiences affect how you view the world and, eventually, how built environments are designed and created. (Whyte and Nikoli 2018)

Our ability to record, process, manipulate, and display information about the built environment has increased because of our rising usage of digital information and our ability to access that information across a variety of personal and professional digital tools. The operation, management, and repair of the built environment have all become more reliant on digital data. As a result, precise data about how the built environment works have become increasingly important for efficient operation and maintenance, as well as addressing sustainability and resilience challenges.(Whyte and Nikoli 2018)

2.6 Digital environments and digital twin

The term "cyber-physical" has started to refer to the increased level of interaction between the operation and use of the physical environment, which includes both built and natural environments. It is a digital copy, which can be updated in real-time with data from sensors and scans and stored in diverse ways. Digital information about a building or infrastructure might be thought of as its "digital twin," as it is in manufacturing industries (Glaessgen and Stargel, 2012). In other words, delivery initiatives are no longer just for producing physical goods but also for creating "digital twins." As a result, while VR can be used to analyse prospective construction and infrastructure projects throughout their development, both VR and AR may be valuable for understanding the state of these physical assets and settings after they have been completed. (Whyte and Nikoli 2018)

Also, it is critical to investigate how a variety of technologies, such as virtual reality and augmented reality, can influence how consumers interact with and update digital information. As a result, consumer hardware components such as head-mounted displays are being created for immersive and augmented visualization capabilities, and links with other technology areas such as machine learning and robotics are being made. (Whyte and Nikoli 2018)

2.6.1 Definition of Digital twin

A digital representation that enables extensive data sharing and contains models, simulations, and algorithms that describe the counterpart's attributes and behaviour in the current world is known as a "digital twin" (Kuhn, 2017).

But as mentioned (Batty, 2018), " The criticism of digital twins is that they abstract only a limited set of variables and processes and rarely involve processes that determine how a city functions in terms of its social and economic functions." (“Digital twins Research Papers - Academia.edu”)

With citizens' having a voice and the chance to influence public decisions for smart, sustainable cities, digital twins for towns will aid urban planners and designers in understanding and informing about the effects of planned urban change. People can reach a consensus through this democratic decision-making process. (Dembski, Ssner, and Yamu 2019)

When it comes to interaction, VR tools, digital twins, and visualization approaches are quite helpful. As one promising method to address not just the complexity of cities but also include residents in the planning process, digital twins have significant promise in the realm of digital tools loaded with quantitative and qualitative empirical data. Digital twins are virtual replicas of real-world physical or intangible items, such as machinery. They provide thorough data interchange and can include models, simulations, and algorithms that describe their counterpart's characteristics and behaviour in the current world (Kuhn, 2017). Additionally, we must remember that a digital twin is not an identical replica. (Dembski, Ssner, and Yamu 2019)

The best way to describe a digital twin is as a repository for simulation, data, and models. The phrase "digital twin" was initially introduced in the context of mechanical engineering, where it has been primarily utilized for several years. Town implementations have only recently been discussed (Batty, 2018). Digital twins can be used in Virtual Reality to improve the sense of the actual world (VR). This immensity enables citizens to better understand the Digital Twin and enables them to contribute. In general, 3D models and visualizations are utilized to overcome a lack of communication and hence help decision-making. In addition to being an innovative method for collaborative planning processes, using a digital twin in VR also makes it possible to reach consensus among participants with various backgrounds. The common learning process associated with educational components is further connected to this. As Glaeser et al. (2006) note with justification, better-educated citizens are more likely to preserve and strengthen democracy. (Dembski, Ssner, and Yamu 2019)

2.7 Metaverse vs. Virtual Reality

2.7.1 What is Metaverse?

The word "metaverse," which means "beyond the universe," is used to express the idea of a future internet version made up of shared, persistent, 3D virtual places connected into what is regarded as an entire virtual universe. The Metaverse, which incorporates all virtual worlds, is also referred to as a general term for a collective virtual shared area.(Moneta 2020)

A 3D holographic avatar, virtual reality, augmented reality, and other modes of communication are all included in the online virtual environment known as the Metaverse. By avatars and virtual reality tools, users of the metaverse interact with one another in a virtual world. This technology enables people to live parallel lives by employing distinctive digitalized avatars. Indeed, the concept of the metaverse is developed long back. Neal Stephenson, an American writer of science fiction, first proposed the concept in his 1992 book "Snow Crash." It expressed the idea that a digital world would soon emerge. Stephenson is currently employed by Magic Leap to contribute to the creation of the metaverse. (“Metaverse: Architects’ Future Realm – Arcace”)

2.7.2 Metaverse architects

It is indisputable that architects make a substantial contribution to the realization of creative initiatives in the metaverse. To develop or improve these spaces, architects and designers are required since people need someplace to live in the metaverse. Those we currently regard as architects will alter with the expansion of this new universe. Thanks to the development in the aim of architecture, we may see a separation between the title of an architect and that of a meta-architect throughout the years. While traditional architecture is essential for enabling our daily activities and providing shelter, meta-architects will focus solely on form, geometry, and visuals. (“Metaverse: Architects’ Future Realm – Arcace”) (Shakeri n.d.)

Architects designing for the metaverse might need to develop new abilities and change their viewpoint. In the metaverse, architects must perform 3D modelling and include expert knowledge from several disciplines, such as user interface, content, character, and even game design. And this will allow a lot more people access to the realm of architecture. The architects may be formed from a wider spectrum of game programmers and designers. More people will be engaged in the process of this new-age architectural design.(Shakeri n.d.)

In addition, this new generation of architects will require instruction in a combination of digital media and 3D technologies. The results are a change that goes beyond the development of architecture, building methods, and materials.(Shakeri n.d.)

The Metaverse has the potential to open new opportunities for the preservation of architectural structures. The metaverse can be the platform where we conserve buildings inside this virtual reality for the benefit of future generations because many buildings have collapsed due to natural or human-made tragedies. It can be viewed as a means of expressing and exploring the architectural history that enables internet users to interact fully with their surroundings.(Shakeri n.d.)

Even for professional architects, designing buildings for the Metaverse is a challenging task, let alone for individuals without a cultural and technical background. Additionally, context is a crucial factor to consider. The environment in which they design is something that architects are taught to analyse and understand. This environment includes both tangible and intangible elements that have been passed down from the past, such as the anthropological history, the landscape, and natural environment, the previous uses of the location, and the memory of the locals. Most of the time, good architects begin their designs with pre-existing elements and then reinterpret them using their cultural background, thought processes, and professional experiences.(Moneta 2020)

We should also consider that all of this does not exist in the virtual world. Direct emotional exchanges are done by a user interface and/or an avatar. Players are alone and share the experience of a virtual space with others, a meta space where there is no weight, no smell, nothing that can be physically touched, and no other memory. Something created specifically for (re) create Metaverse.(Moneta 2013) (Moneta 2020)

2.8 Technical Approaches: information, tasks, and users

In a virtual environment, an interactive, immersive space with visualization capabilities, the city model can be shown to individuals and groups of people. Various levels of detail can be modelled and interacted with using software platforms including AutoCAD, 3DS Max, Sketchup, and VR4MAX. Parts of the interactive model can be retrieved using the software VR4MAX and made available to urban planners for viewing on distant computers in a read-only format. To increase public understanding of the procedure, access to the interactive model (but not the real data) has also been made available. (Tcha-Tokey et al. 2018b)

2.9 Gaming and virtual world

Our Real World (RW) can be seen as an extension of the virtual world, which is a brand-new digital built environment that incorporates not only physical appearance but also cultural and social interaction, aesthetic considerations, and philosophical debates. These critical situations are covered in design education for architecture, but they are typically left out of the education of game designers, programmers, and users who design and construct virtual worlds. Due to this ignorance, virtual world architecture in video games could be widely categorized as film sets with a naive, fairy-tale aesthetic that tries to replicate real-world settings. (Moneta 2020)

Video games are beginning to look and play the same after thirty years since their explosion in the entertainment sector. The novelty value of games that have been developed in the last 15 years has reached its lowest point in 23 years, despite the recent enormous development in internet speed and IT equipment. To increase the aesthetic and "appeal" of video games, developers today invest a lot of money into making them into movies. We could contend that this predicament results from the Virtual World's dearth of architects. Scenography, a copy of architecture without architects, is all that exists. Surprisingly, there are restrictions on design in the virtual world where everything is unrestricted. (Moneta 2020)

Language can be viewed as a collection of language games; it is like a city made up of structures constructed at various points in time and serving a variety of functions. Philosophical Research, L. Wittgenstein, 1953 *30 (Moneta 2020)

Beyond realism, virtual worlds must lay the groundwork for the full realization of their creative and aesthetic potential. To realize a digital spatial revolution, games and virtual worlds need to renounce the depiction of reality and acquire knowledge and application of architectural principles and theories, giving birth to Utopian designs to make the impossible feasible. (Moneta 2020)

To do this, it is crucial to understand the key distinction between real-world and virtual-world buildings. While they are fixed in the former and typically not transformable, the latter can quickly change and re-configure as performing architectures during a dynamic interactive process with the user. (Davis Boyd, Lansdown, and Huxor 1996) In the same way that a parkour competitor uses structures, gamers in virtual worlds can employ them for action and utility. (Moneta 2020)

Since the 1980s, when virtual worlds first popped up in gaming, a digital built environment has been developed from the ground up by software developers, conceptual artists, 3D modelers, game designers, and, on particular platforms and in unique cases, also by users (game players), giving them the opportunity to alter and further create physical content in a virtual world. (Moneta 2020)

As a result, a large number of non-architects who also fill the roles of architects, landscape designers, urban planners, and interior designers are currently creating Virtual Worlds. Game designers receive training in both visual art and technology, but not in architectural, landscape, or urban planning design. (Moneta 2020)

The virtual and physical worlds are interconnected and have an impact on one another. 25 The most played game in history, Minecraft (2009), which gives players access to "digital LEGO," has been successfully used to encourage engagement and participation in architectural and urban planning processes. (Moneta 2020)

On a fictitious level, the real world can affect the virtual world, which is created by other fictitious worlds: books, movies, television, role-playing games, and religion. The historical landscapes that we may observe in many virtual worlds and video games are formed by our past and recent history, which has a factual, more objective impact on the virtual world. (Moneta 2020)

In addition to extending the job of the architect into the virtual world by comprehending the functional facets of gaming and storytelling, it is necessary to grow the abilities and knowledge of architects' designers into the more substantial variety of competencies that only architecture can offer. A productive conversation between the fields of architecture and gaming is what is genuinely required. (Moneta 2020)

2.9.1 Second life as a designer's sandbox

Second Life (SL) is still active after more than 15 years, an extended period for a game because it is not only a game but a space for creativity spanning the Internet and real-world culture. SL is a user-generated content platform, which routinely provides intriguing material ranging from art performances to political campaigns, from land sales to adult entertainment. Second Life was created as an empty place, intended to be filled with content created by users, in contrast to games that have predefined surroundings. This characteristic naturally drew the attention of architects and urban planners. When contrasted to other platforms like Fortnite by Epic Games, which is poised to lead the Metaverse as the potential future of the internet, SL, which was founded in 2003, appears hopelessly antiquated. (Park 2020) But throughout the past seventeen years of operation, SL has undergone constant change because users are not visitors but residents who create their own homes, cars, and other oddities using a simple 3D modelling program that is integrated into the platform. (Moneta 2020)

In addition to being a great platform for distance learning and a great shared space for researching the relationship between architecture and gaming, Second Life (SL) offers a variety of opportunities for interaction and creative experimentation. It is still relevant nowadays in fields such as theatre, performing arts, architecture, urban planning, fashion design, and psychology.

When approaching architecture in Second Life, as in any virtual world, the first thing to think about might be the building's architectural purpose, which might be to let avatars move around and truly experience the spaces while also appreciating aesthetics beyond functionality. Second Life enables users to participate in virtual reality experiences without the use of a headset.(Moneta 2020)

2.10 Conclusion

This chapter begins to answer the question: **what are virtual reality systems? How have the built environment and urban planning been exploited, designed, and developed using virtual reality?**

Virtual reality (VR) is a computer environment with real scenes and objects that makes the user feel immersed in their surroundings. ("Feature: how is immersive technology being used in healthcare? - HTN")

By analysing virtual reality systems, we realize that the **goal** of virtual reality systems is to provide engaging, naturally interactive, and comprehensive experiences in a virtual environment. Thus, a wide range of virtual, augmented, and augmented reality technologies **are used to represent the built environment and to make decisions about the operation, design, and construction of new structures and infrastructure.**

The key is well-structured digital data that consumers may have access to, regardless of location, format, or device, with the globalization of computers. Digital technologies, for instance, might improve our understanding of the interactions between the built and natural environments, **giving us a wider perspective of the physical world**.

In addition, with the development of this technology, some organizations are trying to make the system more tangible and bring experiences through smell, hearing, touch, and even breathing, such as olfactory, haptic kinaesthetic, etc. Considering the history of virtual reality systems, we can have a better overview of their future. Virtual reality and augmented reality systems have become smaller, cheaper, and more compatible over the past few decades thanks to the exponential increase in processing power, which has also increased the sensitivity of input devices and the resolution of output devices.

Access to VR systems for users in the built world has expanded because of this increase in computing power, and new applications have become available. Moreover, we must consider privacy and security concerns as well as the growing technology integration and life cycle as we become more experienced users of digital technologies. **Digital technologies, for instance, might improve our understanding of the interactions between the built and natural environments, giving us a broad perspective of the physical world**.

As was previously stated, digital engagement tools have become more powerful and widespread. As we use digital information more frequently and have access to it through a range of personal and professional digital tools, we are better able to record, process, manipulate, and display information about the built environment. As a result, precise data about how the built environment works have become increasingly important for efficient operation and maintenance, as well as addressing sustainability and resilience challenges.

Accordingly, the term "cyber-physical" has started to refer to the increased level of interaction between the operation and use of the physical environment, which includes both built and natural environments. It is a digital copy, which can be updated in real-time with data from sensors and scans and stored in diverse ways. Digital information about a building or infrastructure might be thought of as its "digital twin," as it is in manufacturing industries.

A digital twin is a tool for a digital duplicate of a physical thing or process that exists in real-time as a virtual representation. Digital twins can be used in Virtual Reality to improve the sense of the current world (VR). This immensity enables citizens to understand the Digital Twin better and enables them to contribute. In general, 3D models and visualizations are utilized to overcome a lack of communication and hence help decision-making. In addition to being an innovative method for collaborative planning processes, using a digital twin in VR also makes it possible to reach consensus among participants with various backgrounds.

Furthermore, the metaverse, which is an integrated network of 3D virtual worlds, these days, is a trending topic in the world. Metaverse means beyond the universe and is used to express the idea of a future internet version made up of shared, persistent, 3D virtual places connected into what is regarded as an entire virtual universe. The metaverse, which incorporates all virtual worlds, is also referred to as a general term for a collective virtual shared area. The metaverse has the potential to open new opportunities for the preservation of architectural structures. The metaverse can be the platform where we conserve buildings inside this virtual reality for the benefit of future generations because many buildings have collapsed due to natural or human-made tragedies. But we should consider that, even for professional architects, designing buildings for the metaverse is difficult.

By considering the exact meaning of virtual reality systems and the historical background and environment, we can subcategorize systems like Digital Twin, Metaverse, and some virtual environments like sandbox, Second Life, ETC. We can prepare for the future and use them as a solution for simulating and planning for the future of cities.

Chapter 3: Virtual cities

3.1 What is virtual city?

Cities are where people live, work, and play. Most people in the world live in cities, and as a result, professionals working in the built environment face the problem of meeting rising demands for housing, transportation, and resources. Interventions to construct new structures and infrastructure are made within the context of the areas of the existing built environment that are continuously inhabited. (Whyte and Nikoli 2018)

Virtual Reality systems give experts visual access to digital information about this environment through initiatives to digitally model and simulate the real environment, users, and services. Virtual models can be used to democratize planning, test many future scenarios, understand how the built environment operates, and train emergency response, maintenance, and operations employees across scales, from buildings and neighbourhoods to infrastructure and cities. (Whyte and Nikoli 2018)

This is accomplished by modelling behaviours inside the constructed environment as well as its physical features. Professionals have been experimenting with virtual reality uses for managing, utilizing, and planning the built environment for the past few decades. In this chapter, we take a close look at this varied range of uses and how virtual reality systems are used to show data about urban areas, cities, and neighbourhoods to both enhance the functionality of existing structures and infrastructure and to create brand-new interventions.(Whyte and Nikoli 2018)

Many cities throughout the world are constructing or considering developing virtual city models. While significant research has been done on the many technology solutions that potentially support virtual city models, less has been done on their long-term viability and management. (Pinto 2014)

A virtual city is a collection of digital products and information resources made up of a large, distributed database of heterogeneous documents of various digital genres, such as texts, photographs, maps, animated images, and the like, deployed to provide services aimed at facilitating social or spatial navigation in a virtual or physical space. (“Communication of Social Agents and the Digital City – A Semiotic ...”) (Ishida 2000)

From reviewing the history of virtual reality, the life span of virtual city projects is short due to technological changes.

The virtual city concept is applied in three different but related ways. First, a digital city is a representation of a real city, town, or village on the Internet, offering citizens all kinds of information about the real city, as well as communication and social interaction opportunities. Second, a digital city is one with modern information and communication infrastructure that is required to keep pace with global economic dynamics or to reinvigorate the local or regional economic structure. Finally, the term "virtual city" can refer to systems that employ the city paradigm, such as virtual communities for collaboration and participation. (Ishida 2000)

The constructed environment is assumed to be the referent is one conception of the digital city. The digital city is linked to the physical city in the same way that suburbs are related to cities. The expected outcome is a rejuvenated civic culture with social cohesion, greater localism, and reconnecting of previously fragmented social, economic, and cultural elements of society. (Ishida 2000)

This vision of the digital metropolis is reflected in the efforts of tele cities members who worked on the Info Cities project. Info Cities aims to test the use of information and communication technology (ICT) to deliver integrated public services and achieve a "one-stop" point of service delivery. Education, health, transportation, culture, electronic commerce, and public information were the service categories chosen for the feasibility phase. Info Cities also expects to promote residents' access to public and municipal services, as well as provide businesses and professionals with value-added services. (Ishida 2000)

However, in a globalized world, "one-stop" public access to local information is not the only way to think about the digital city. In another variation, the Teleport is utilized as a marketing tool to attract investment and worldwide enterprises by serving as the focal point for urban growth or redevelopment, with new offices, industrial, and high-status residences. (Ishida 2000)

In a third version, virtual space provides a context for interconnected networks that form virtual communities or digital cities whose identity and existence are purely defined by their online surroundings. The virtual community develops identity and delivers services to its residents through digital connectivity without the need for physical touch, much like a suburb without a city or a symbol without a site-specific referent.(Ishida 2000)

Urban models provide examples of what is now available with current technology, but many cities now have several three-dimensional models to improve the situation. Many areas of cities have been modelled, even in cities that have not yet developed an urban model to activate new project ideas. (Horn, 2009). This may be one of the key financial considerations in developing a multi-purpose urban model that can be used for multiple projects over time. There are many benefits and efficiencies that can be achieved by using 3D city models. If these models are used in the development planning phase, the public may have more opportunities to participate. However, virtual city models have been applied in tourism, urban planning, architectural visualization, pedestrian and transport modelling, culture and heritage, and participatory and social interaction. (Pinto 2014)

3.2 History and background of digital cities

Modelling activity in Europe: According to a recent survey of virtual city projects that were conducted between September 2008 and January 2009, there are several common problems in hosting and managing city models. Cities that profess to follow more than one model exist. For instance, London has at least four virtual cities, each with a larger size, use, and level of realism (LOD). It was discovered that Hamburg and Paris share at least two city models. Germany's approach to city modelling technology has led to the modelling of several German cities. Berlin's city model, which now contains three-dimensional geometry and geographical data from a variety of sources, has attracted continuous engagement from the city's-built environment community. When starting to build a city model, city authorities must make a number of considerations.(Pinto 2014)

Some nations, such as Sweden, develop 3D mapping data for entire regions and make it accessible to inhabitants (Hallebro, 2006). An initiative to model every building in Denmark by Blom ASA (2.2 million buildings approximately) demonstrate what can be achieved using recent advance city modelling technologies.(Pinto 2014)

3.2.1 Development and technical

The city can be viewed as a complex system, or a system-of-systems, which involves various transportation, water, waste, power, and communication systems when it comes to managing the built environment (e.g., Kasai et al., 2015). Although they are normally constructed individually, these systems are open and interdependent systems that interact with one another and the natural environment. We depend on them to operate well. Professionals may be able to experience city operations using virtual and augmented reality, sharing expertise across organizational and disciplinary boundaries to help cities make better decisions as they work to combine data from various utility firms and municipal departments.(Whyte and Nikoli 2018)

Understanding the organizational, technological, and financial implications over the short, medium, and long terms requires an examination of the needs. Options for data collection and 3D modelling should be considered with model administration, updating, and standards. timescales, legal concerns, and estimated expenses.

3.2.2 Case study: Virtual Newcastle Gateshead

Gateshead is a northern English town. It is located on the southern side of the River Tyne, opposite Newcastle, and is connected by seven bridges. The Millennium Bridge, The Sage, and the Baltic Centre for Modern Art are some of the town's most well-known examples of contemporary art and architecture.

Virtual Newcastle Gateshead (VNG) is a collaboration between Northumbria University, Newcastle City Council, and Gateshead Council to develop a three-dimensional computer model of Newcastle and Gateshead's urban core districts.(Northumbria university new castle 2019)

The Virtual Newcastle Gateshead (VNG) project's goal is to find ways to build an interactive, virtual representation of Newcastle Gateshead that may be maintained and used for a variety of purposes. The idea of a virtual city model of an English city (Newcastle Gateshead) dates to the middle of the 1990s, and several significant developments in both Newcastle and the nearby Gateshead have made use of interactive computer models to aid in envisioning development proposals. Since then, and particularly since 2000, there have been significant improvements in hardware and software performance, three-dimensional computer modelling, and virtual reality technologies, leading to more accessible means to prototype cities and buildings.(Pinto 2014)

By giving architects and developers the tools to precisely examine the impact of design concepts within their urban environment, the VNG model presents a special potential. The

VNG model offers a more effective and efficient communication tool as part of the urban planning process. (Northumbria university new castle 2019)

The current model is based on surveying methods using laser scanning and aerial photogrammetry. The model will need to be built on a database structure in the future to support frequent update processes and effective management.

The VNG project's goal has been to find ways to develop a single, accurate, interactive model of Newcastle and Gateshead that can be utilized for a variety of purposes. It has been acknowledged that a digital model needs to be successfully managed, consistently updated, and incorporated into current working practices and procedures to be successful and sustainable. These organizational requirements are just as critical as having enough technical solutions. (Northumbria university new castle 2019)

The three stakeholders in VNG realized that an effective management strategy, frequent updates, and integration into current working procedures and processes are necessary for a digital model to be successful and maintain sustainability. These organizational needs are just as crucial as putting in place the proper technical solutions. Additionally, the ability to access and share the data in VNG with other users will support the lifespan model. A thorough examination of the requirements revealed the necessity to create the model specifically to facilitate urban planning, interactive navigation, and remote access while taking security concerns into account.(Pinto 2014)

The technological methodology utilized by VNG involved obtaining the first 3D model data from a UK-based data supplier that employed aerial photorealistic rendering as a method of data collection. They also made use of land-based laser scanning technology. Also, If the modelling process is not supported by strong business goals, the sustainability of city models may be challenged. The primary goals of VNG were to operate as a business, bring in money, and become self-sufficient. It had to be handled daily and to a standard that satisfied developers, planners, architects, and users.

The fundamental issue with this system is that it can only be implemented by multidisciplinary and inter-organizational teams working together to integrate city model technology into the current process. The most difficult part is still updating the city model.(Pinto 2014)

Because there is not software designed expressly for urban design and there are not many computational tools to help with the interior environmental design of individual structures, analytical tools aren't applied to urban design. Numerous software programs are available for analysing heat, light, sound, and energy consumption. More attention might be paid to how a space works in terms of pedestrian comfort and activity by simulating and analysing performance elements using virtual city data, improving the likelihood of success and the multifunctional use of a virtual city model. This led to the creation of computer software specifically aimed at simulating urban design performance utilizing data from virtual cities.(Pinto 2014)

Making decisions about technical alternatives, data acquisition, integration with current geographic systems, the development of standards and protocols, and the hosting of intellectual property are all part of the process of creating a virtual city. How keep a virtual city model current and up to date is a major difficulty because the availability of an appropriate updating mechanism can directly affect how long a city model lasts. Aiming for a manageable degree of details can help to address the difficulty of keeping a model current (LOD). Models with lower LOD can be updated more readily than models with greater LOD.(Pinto 2014)

Future city planning and design can be assisted using microclimate datasets to create information-rich virtual city models that can be utilized as analytical tools. Geometric characteristics, climatic data, and pedestrian movement data may be included in virtual city models created on a database platform. As a platform for various applications as well as an analytical and forecasting tool, the virtual city model itself might be used to evaluate how well metropolitan areas work. (Pinto 2014)

Local architects, developers, and visualizers have recognized the value of Virtual Newcastle Gateshead. It has been used for different projects, from small-scale buildings to Newcastle's largest projects. Reviewing this case shows us the capability of this type of project, which is a collaboration with academic organizations that could give us a result in a more accurate way.(Northumbria university new castle 2019)

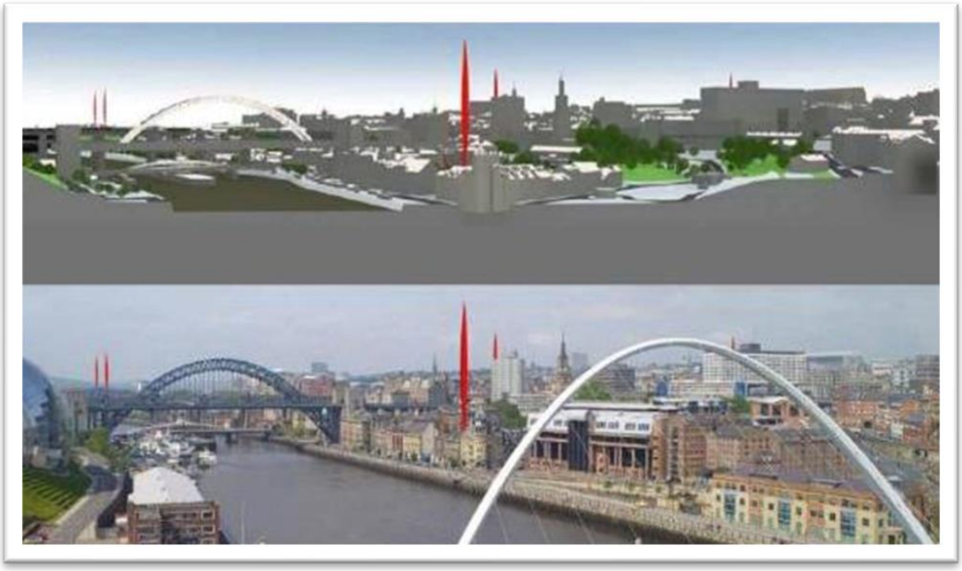


Figure 3.1. Verification of accuracy of Virtual Newcastle Gateshead. Source: Horne,2009.

3.3 Architectural design theory in virtual environment

A definition of architecture that embraces and connects the domains of physical and virtual architecture is first presented. In response to a need or program, architecture is the organization and definition of meaningful space that creates a place (Ching 10). It is often referred to as the spatial, sensory manifestation of civilization or culture (Campbell, "Virtual Architecture").

Architecture is defined in each of these definitions as a notion or idea that can take both physical and virtual forms (Figure 1.1). (Campbell 2003)

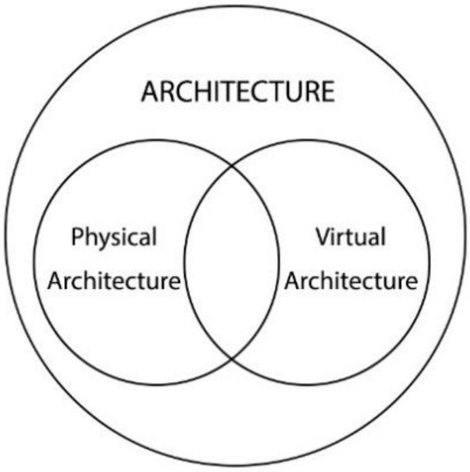


Figure 3.2: Venn Diagram Relating Physical Architecture to Virtual Architecture. (Campbell 2003)

Since the 1990s, research in architectural design has examined how it has evolved in cyberspace. (Bourdakis and Dimitrios 1999) Due to several creative designers (from Archigram to Asymptote) and theoretical advancements, architecture began to bleed over into cyberspace in the early years. Later, digital intrusion in this area has mostly progressed into the form-based design, gaming, and parametric architecture. In the meantime, post-capitalism, globalization, the demise of traditional values, and the absence of reliable references had an impact on RW's architecture. (Bocchi and Mauro Ceruti 2007) Significant developments in automation, information technology, and the fourth industrial revolution have accelerated the globalization of architecture and destroyed local individuality and character. (Ibelings 1998)

Koolhaas, Libeskind, Hadid, and Gehry were among the urban designers and architects who abandoned formal design orthodoxies and principles in favour of experimenting with innovative talent that sparked dramatic, outlandish comments about the urban environment. (Saitta 2011) This generalized globalization of means and methods led to Utopia, a disregard for the local environment, the destruction of local identity, Genius Loci, and social purpose. This tendency is reflected in the architectural design of the virtual world. (Moneta 2020)

Frank Lloyd Wright's opposing strategy, which was aimed at the dissolution of the city in favour of more widespread, decentralized communities, helped virtual cities grow organically. Le Corbusier's application of Utopian and visionary urban planning, for example, with his centralized and structured model, was key to helping design virtual environments that could be easily navigated.(Ingram 1997) The important task of navigation and orientation in virtual environments was solved with the help of Kevin Lynch's findings on the perceptual form of urban environments (Lynch 1964), and in particular, the fact that users understand their surroundings in consistent and predictable ways by forming mental maps. This improved the users' spatial awareness. (Campbell 1996) Paths, edges, districts, nodes, and landmarks are the five primary components that humans use to orient themselves with a mental map. Lynch coined the term "way-finding" to denote a consistent usage and organizing of these cues from the outside environment. These components, as well as their interactions, have been extensively used in academic studies on the topic to establish the architectural design principles of virtual worlds. (Moneta 2020)

Christopher Alexander, who employed computation and structure to create tools to enhance towns or build houses before publishing his well-known book A Pattern Language in 1977, is another significant contribution. Contrary to the conventional urban planning method, which imposes preconceived grids, zones, roads, and structures on human activities. (Alexander 1977) His approach has been utilized to create new software technologies like Object-Oriented Programming, Interaction Design, and "design patterns," which are found in Macs, iPhones, and many other computer systems and video games. ('The Pattern Technology of Christopher Alexander' n.d.) The Sims (two thousand), one of the most popular video game franchises ever, was also influenced by A Pattern Language. (‘Gamasutra - Designer’s Notebook: The Role of Architecture in Videogames’ n.d.)

Pattern Design has evolved into Generative Design (GD) in recent years, which is another technique that uses computational processes to create designs for virtual worlds and is backed using a grammar intended to officially define design languages for virtual worlds. (Gu 2006) The grammar of GD is built on a set of rules that designate a particular "style" of architecture.

Models used for planning may contain information that is quite different from models used to comprehend specifically built-environment operations. The ability to experience the city from both a street-level view and an interactive bird's-eye view is one of the unique features of VR systems for planning. In her critique of modernist planning, Jacobs (1961) emphasized the importance of experiencing a city on the ground level. She claimed that a bird's-eye view of a city is oblivious to the true beauty and power of great cities. She suggested that excellent cities should have intriguing streets as well as well-planned neighbourhoods with the appropriate amenities. The quality of streets as locations, however, is disregarded in city planning since the user is restricted to a perspective outside the model.

To offer this street-level vision, new kinds of representation beyond maps, models, and plans were sought long before the phrase "virtual reality" was even coined.(Whyte and Nikoli 2018)

3.4 Urbanising cyberspace

Professionals use digital information to simulate, test, and make informed choices while planning, constructing, and maintaining built environment projects of any scale. They usually generate data in discipline-specific applications that apply a variety of representation formats (e.g., diagrams, 2D or 3D outputs) and data structures. These computational methods are used to create models that may subsequently be viewed via virtual or augmented reality to assist with project planning, evaluation, and adjustment. Professionals must assess which visual interfaces provide the most beneficial experience for each task. VR and AR applications may not always provide the best experience due to their unique characteristics. Understanding the nature of the tasks at hand is critical, which includes identifying user groups, anticipating what outputs they require, and determining what information is available.(Whyte and Nikoli 2018)

3.5 The bridge between real and virtual cities

An increasing number of studies show that knowledge of the physical city may be used to design digital cities, which either connect the real and virtual worlds or build virtual cities for digital populations [14]. It has been noted that an infrastructure intended to link data is different from one created to support the population. Both infrastructures have a significant role in encouraging and developing community involvement as well as in shaping and limiting interpersonal communication. The significance of the symbiotic relationship between physical and digital cities should not be lost in the infatuation with technology and the problems that the digital city presents. (Ishida 2000)

However, because the nature of space in the virtual world differs fundamentally from that of the real world, the virtual world's architecture requires its own theory and methodology. (Bourdakis and Dimitrios Charitos 1999) For this reason, the virtual world was chosen as a platform for study and experimentation with the aim of (re) establishing the function of founding architecture using the principles of functional organization in the virtual world. (Maher et al. 2000) The virtual and physical worlds are interconnected and have an impact on one another. (2009) Minecraft (Bartle 2004)

To bridge the past and the present and strengthen the users' relationship with a particular setting and architecture, virtual worlds can preserve and represent our cultural memory through their physical appearance. (Veltman 2017)

Architecture is the manifestation of a civilization as a significant place, whether it be physical or digital. Although each has its own limitations and context, physical and virtual architecture both use an architectural organization to organize the forms and spaces in their surroundings. Both attempts to define space to create a meaningful place and both must permit the participant to form a mental map of the environment to orient and move about it. For the participant to handle transitions, the absence of time and place in the virtual world necessitates unique consideration and expression of its design. The creation of an online exhibition of virtual worlds serves as an illustration of these problems. (Campbell 2003)

One can evaluate the benefits and drawbacks of architecture as a tool for social interaction, regardless of whether it exists in the physical or virtual world, by using physical architecture as a case study of how it relates to the former. (Campbell 2003)

Because city expert plans are primarily visual, virtual reality (VR) can be utilized to successfully overcome this barrier, providing a greater grasp of how the smaller picture fits into the larger, as well as more thorough input and designs. It serves as a link for information between the technical and real world and will undoubtedly become more significant as technology advances.(Gowling WLG 2019)

Because they are an online representation of a genuine city or city area, virtual cities stand out from other websites because they are linked to a specific location and inspire a feeling of the place. However, we concur with Firmino (2003) that a virtual city is more than just the digital arrangement that appears on the computer screen. It is a sophisticated urban setting. It undermines the notion of the city as something solid, as a material artifact, to only think of virtual cities as what can be seen on the screen, rather than seeing them as the result of intricate social and economic processes (Batty, 2001). (Fernandez-Maldonado and Ana Maria 2005)

It is time to think about the next scale, the city, as BIM (Building Information Modelling) progressively gains more traction in the architecture and engineering of individual structures. Virtual city simulations could have applications in actual city planning, allowing us to move from "flat" GIS to three-dimensional information modelling that includes terrain, infrastructure, buildings, and public spaces. Virtual models help us design, understand, and embed information just like physical models do. Could the solution to "smart cities" lie in virtual cities? (Philipsen 2013)

3.5.1 Case study: Seattle

A metropolis on Puget Sound in the Pacific Northwest, Seattle has thousands of acres of parkland and is surrounded by water, mountains, and evergreen woods. The largest city in Washington State is also the location of a sizable tech sector, including the corporate headquarters of Microsoft and Amazon. This city is one of the earliest cities to offer virtual tours.

Seattle has created a smart 3-D model of most of its central business district that not only faithfully replicates the real Seattle to an astounding degree but has also been loaded with data about several types of structures. When used to the neighbourhood and city levels, this operates similarly to BIM when applied to a single building. Amazingly, the Seattle model even incorporates underground infrastructure, which is hidden from view. A video that showed the modelled Alaskan Way Viaduct in an earthquake and how it collapsed after experiencing some strong vibrations was featured in The Atlantic Cities.(Philipsen 2013)

Figure 3.3 Seattle's citywide model. Image Courtesy of Autodesk (Philipsen 2013)

The video also showed fires breaking out when gas lines ruptured and buildings and electricity lines swaying and partially toppling beside that disaster. All of this was done based on the engineering of these structures and an actual big earthquake, not for some fictitious horror film about King Kong scaling the Empire State Building. Naturally, the film effectively illustrated the rationale behind Seattle's decision to carry out the nation's second "big dig" (after Boston), which entails burying the Alaskan Way Road in a sizable drilled underground tunnel. (Philipsen 2013)

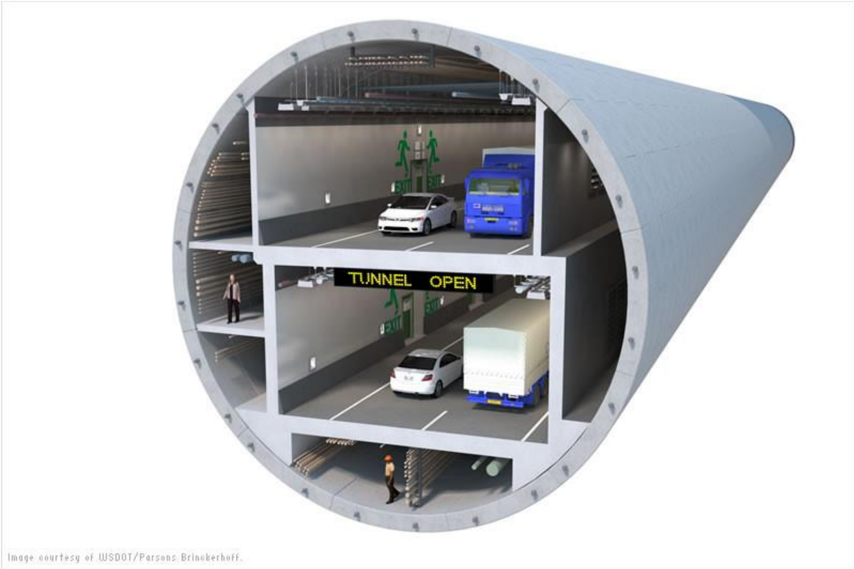


Figure 3.4 The Proposed Alaskan Way Tunnel. Image © Parsons Brinkerhoff (Philipsen 2013)

Those who have visited Seattle are aware that, like Boston, the issue at hand is an elevated roadway that divides the city's centre from its coastline. While the I-95 tunnel in Boston has been finished and normal life has resumed, Seattle's double-decker Alaskan Way is still open, but their huge excavation has started. (Philipsen 2013)

Returning to the "smart city" and 3-D modelling: What could be more exciting than incorporating all the information presently streaming through a thousand different channels into a unique location, the virtual model of the city?

In many ways, it would be like GIS maps, where any number of informational attributes, including third-dimensional properties like heights, may be included in shape files. Indeed, many city GIS shape files include building heights that were either manually transferred from old manual databases or gathered by LiDAR, laser information from flyovers that provides read-outs of building heights in the same way that sonar has mapped the seafloor and ocean depth. For cities with high-quality GIS maps, the obvious next step would be to simply "extrusion" their buildings from the combined footprint shape file and height. (Philipsen 2013)

3.6 Characteristics of digital city based on digital twins

A digital twin is a digital version of a real-world thing like a system, person, place, or object. Digital twins were first intended to be used in simulations with precise models of individual components to enhance manufacturing processes. However, it is now possible to develop digital twin smart cities thanks to glowingly accurate building information models (BIM) and substantial amounts of data produced by IoT sensors in a smart city. The public can explore a detailed 3D model of a city that has been published online to see suggested changes to urban planning and policy. Before putting these judgments into action, this enables simple transmission and public transparency.(White et al. 2021)

The advantages of a digital twin city have been evaluated based on real-time data collected from preinstalled Internet of Things (IoT) sensors (e.g., traffic, energy use, air pollution, and water quality) for managing complex city systems. Also still, sensor-based reality data is unlikely to be sufficient for providing dynamic spatiotemporal information on physical vulnerabilities. Understanding the status of physical vulnerability in cities can help city decision-makers analyse associated potential risks in metropolitan areas for data-driven infrastructure management during extreme weather events. (Ham et al. 2020)

Smart cities are fascinating test beds for data mining and machine learning because of the data they create (Mohammadi & Al-Fuqaha, 2018; White & Clarke, 2020). Machine learning, the internet of things, and big data can be used to tailor the services offered to city residents (Chin et al., 2017; White, Palade, et al., 2019). (White et al. 2021)

A digital twin can be created and updated when the physical equivalents change because of the additional data made available by smart cities, artificial intelligence, data analytics, and machine learning. (Kaur et al., 2020). A digital twin is a connection between the virtual and real worlds that enables data analysis and system monitoring to detect issues early on, save downtime, and even utilize simulations to prepare for the future (Boschert & Rosen, 2016). The manufacturing industry has been the primary application for digital twins, but other fields of research and commerce are starting to explore new applications. A perfect digital twin would have a full, current dataset of all the data on the object or system and be identical to its physical counterpart. (White et al. 2021)

The level of detail used, and the range of the data provided will determine how accurate and valuable a digital twin is. Before taking actual physical action in the real world, digital twins enable simulation of a variety of possibilities to determine the advantages and disadvantages of each strategy. This is essential in instances involving safety-critical decisions, where there may be several competing proposals but only one can be adopted.(White et al. 2021)

When rescuers acted, it was the best-case scenario that had been tested thanks to the employment of a digital twin. Applications for digital twins can be found in numerous industries. Digital twins can be used to simulate urban planning and policy choices using the data produced by smart cities.(White et al. 2021)

By using the digital twin, it is possible to involve the public and gather a variety of informed feedback on crucial policy and urban planning issues. The results of simulations for skyline and green space planning show how user inputs and ideas may be collected to provide more information for guiding urban planning and policy decisions and the possibility of additional reviews before the final decision. In the green space planning simulation, items can be left unchecked to encourage residents to submit their suggestions, such as putting a playground in a park. As can be seen in the user tagging simulation, these basic form-based strategies can be extended to a tagging model.(White et al. 2021)

Citizens can engage with every object in the digital twin in this way and tag issues or suggestions. The appropriate government department can then get these issues or ideas along with the precise location of the issue. Numerous more urban planning choices and policies can be made using a digital twin. The model's 3D nature makes it possible to simulate uncommon situations that call for 3D data, like flooding in a metropolis. This can therefore influence the city's decision regarding which parts of the city should be evacuated first and where sandbags should be placed.(White et al. 2021)

These simulations can be expanded to analyse potential options for urban planning in a smart city, such as the effects of altering a footpath's gradient or adding more street furniture on various pedestrians, including children, the elderly, and adults. We intend to supplement the open data we utilize for the simulations in upcoming work with information from additional IoT services in the neighbourhood. The city council, local individuals, or businesses, or both, may offer these services. With more data, simulations might be more accurate and include local traffic, noise pollution, and crowd density data that is updated in real time. This model of a digital twin with mobility data can be modified for a variety of various scenarios. Numerous other scenarios that were not looked at in this paper can be applied to this digital twin model using mobility data.(White et al. 2021)

3.6.1 Related work

Virtual Singapore, a three-dimensional (3D) city model and data platform, serves as an illustration of a digital twin of a city that is still in development. Digital twins are exact digital copies of real-world objects, whether they are alive or dead (El Saddik, 2018). Digital twins are becoming increasingly popular as tools for data, services, modeling, and connection to the real world become available (Qi et al., n.d.). Digital twins are living digital simulation models that update and alter in conjunction with their physical counterparts thanks to the integration of the internet of things, machine learning, artificial intelligence, and data analytics (Luo et al., 2019). To represent the physical thing in almost real-time, a digital twin continuously learns and updates itself from various data sources. The system can learn from itself, from other digital twins with similar characteristics, or human subject-matter experts. A digital twin can incorporate historical usage data into its digital model to learn from it. (White et al. 2021)

NASA originally defined digital twins as a model for future NASA and U.S. Air Force vehicles (Glaessgen & Stargel, 1818). To identify any potential issues with safety or efficiency, a digital twin would enable ultra-high fidelity simulation using data from the vehicle's onboard systems, maintenance history, and all accessible historical and fleet data. Since they may bridge the gap between virtual and physical space at various points in the product's lifetime, they have since been used in several manufacturing initiatives (Tao et al., 2018). Using a digital twin, the product can be tested at every stage of the design process to make sure it is practical, safe, effective, and reliable (Rosen et al., 2015). Control and experimentation of a complex system are made possible by a digital twin (Grieves & Vickers, 2017). This has led to its application in a variety of intricate systems outside of product design and manufacture. (White et al. 2021)

The information gathered from smart city services can be used to establish digital twin cities (Mohammadi & Taylor, 2017). A city's spatiotemporal data can be modeled and seen using virtual representation. To build a digital twin of a city, one can take advantage of many of the recent achievements in smart cities around the world in integrating dependable ICT systems (Mohammadi & Taylor, 2019; White et al., 2017). Singapore, often known as Virtual Singapore, has made an early effort to build a digital twin smart city (Soon & Khoo, 2017). This initial method has a few drawbacks, including the lack of urban mobility data and the fact that the model has not been made publicly accessible, making it impossible for users to provide feedback or engage with it. The Centre for Digital Built Britain at Cambridge University is developing a road map for digital twin programs, which are still in their preliminary stages (Enzer et al., n.d.). The road map outlines the essential components and stakeholders that, when working together, would make digital twins successful throughout the built environment. (White et al. 2021)

Private businesses have started to appear in the Digital Twin Smart City field, including City Zenith, Agency, which Bentley purchased, and smarter Better Cities. All these businesses, though, are private, do not release their models to the public, and charge hefty license fees. Our strategy is freely available online, enabling anyone to interact with the model and use it in further digital twin initiatives. (White et al. 2021)

A publicly available 3D model was used to create a digital twin of the Docklands neighbourhood in Dublin, Ireland. By incorporating a planned skyscraper into the skyline along with more green areas and parks, they demonstrate how the model may be utilized for a variety of urban planning and policy issues. Users may quickly identify issue areas in the city using the model, which is accessible online, and complete forms to request changes in their neighbourhood. As a result, more data is produced, which the digital twin might use to develop specific issue areas in the city. They also demonstrate how our digital twin may be utilized to model different urban mobility scenarios using pedestrian mobility and the impact of river flooding on the city. (White et al. 2021)

3.6.2 Digital twin smart city design

A digital twin smart city builds on several informational tiers present in the city. In our digital twin smart city concept, which is depicted in Fig. 3.2, we specify six levels. The city's terrain, buildings, infrastructure, mobility, and IoT devices are all further described in the first five layers that are built on top of one another. Data from the city is gathered by the Digital Layer/Smart City and passed to the Virtual Layer/Digital Twin. The Digital Twin runs additional simulations about building location, mobility optimization, and the construction of renewable energy sources like offshore wind farms using the data gathered in the smart city. Once implemented in the real world, this information is then transmitted back through the model's layers.(White et al. 2021)

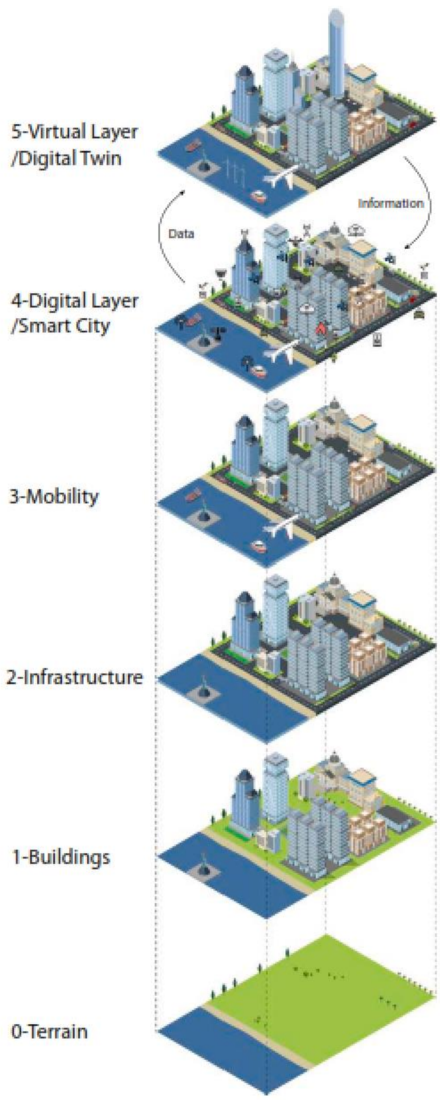


Figure 3.5 Layers required to develop a digital twin smart city (White et al. 2021)

0. Terrain

The landscape upon which the city is erected is the zeroth layer of the digital twin smart city concept. Here are some basic facts about the city, such as whether areas are on the shore, whether there are any rivers or canals in the area, whether there are any slopes or high hills, and which areas are made of sand. Which portions of the city have soil that is suitable for growing crops, and which areas have soil that is poorly drained and may result in issues like landslides or flooding during periods of heavy rain? It is possible to include this data in the model by using a soil map, as shown in Fig.3 2.

1. Buildings

Current city buildings are included in layer one of the digital smart twin city models. These structures feature extremely precise building information modelling (BIM) models that can be utilized to create a digital twin of the structure. Stereoscopic aerial photography can also be used to create 3D building data.

2. Infrastructure

The city's current buildings' surrounding infrastructure is added in Layer 2 of the digital twin smart city model. For a community or business to function, essentials related to the physical structures and services (such as roads, electricity sources, and telecommunication) are required. Open Street Map, which includes data on power, public transportation, highways, motorways, amenities, and telecoms, can provide this infrastructure data. To add gradient information, which may not be present in open street maps, data from the 3D mapping process can also be used.

3. Mobility

The infrastructure and building layers are joined by mobility in Layer 3 of the digital twin smart city paradigm. The mobility refers to both the movement of individuals during their everyday travels and the movement of things that support them in various facets of their lives. Urban mobility simulations can be performed using software tools like SUMO (Lopez et al., 2018). Walking, cycling, motorized two-wheelers, and generic parametrized vehicles are only a few of the several modes of mobility supported by the SUMO simulator. Railways and canals are other models that are accessible. Utilizing the Traffic Control Interface, this program may be linked to the Unity 3D model (Traci). Additionally, Unity can be used to develop and improve traffic modes by introducing extra behaviours that the simulator does not account for. Incorporating other pedestrian types like adults and the elderly is something we are interested in doing.

4. Digital layer/smart city

With numerous projects aimed at integrating IoT sensors in the city to gather data, the digital layer/smart city layer has become extremely popular.

The management and monitoring of traffic and transportation networks can then be done using this data. (Menouar et al., 2017), power plants (Oldenbroek et al., 2017), utilities (S´anchez et al., 2013), water supply networks (Parra et al., 2015), waste management (Medvedev et al., 2015), crime detection (Chiodi, 2016), information systems (Abdel-Basset & Mohamed, 2018), schools (Williamson, 2015), libraries (Johnson, n.d.), hospitals (Pramanik et al., 2017), and other community services (Hashimoto et al., 2015; Jalali et al., 2015).

The digital layer/smart city, as seen in Fig. 1, oversees collecting all the data from the preceding levels required for simulations in the virtual layer/digital twins. The knowledge from the simulations is then circulated through the city's tiers. Citizens, mobile assets, and devices that may be dispersed around the city can all provide data. Residents can submit data to the city administration using their smartphones and smartwatches. The linked vehicles in layer four of Fig. 1 can send traffic data to the traffic authority to help plan lights and improve traffic flow.

Many intelligent trees contain moisture sensors at the roots to make sure they get watered at the right times. A lot of interconnected CCTV cameras are spread low latency over the city as a crime deterrent and as proof of illegal activity. Many 5G mobile towers are dispersed throughout the city, offering quick and low-latency internet connectivity. One of the city's six tower buildings has just sent an alert to the fire department after connected fire equipment detected smoke in one of the units. To gather information for the potential construction of an offshore wind farm, wind sensors have been placed on the boats and launched offshore close to the monument.

5. virtual layer/ Digital twin

The information produced by the digital layer/smart city is built by the virtual layer/digital twin. The arrows in Figure 1 illustrate the relationship between the virtual layer and the digital layer. The digital layer transmits information on the city's movement, infrastructure, and geography. This information is utilized to run simulations in the virtual layer that can then be relayed as data through the city's layers. For instance, wind data is being gathered offshore at the digital layer in Fig. 1. The feasibility of using offshore wind turbines to satisfy the city's renewable energy targets is then simulated using this data.

The wind data gathered in the digital layer can be used to affect the size and placement of the turbines by creating a fully accurate digital twin of the turbines. The aesthetic impact of the turbine placement can then be assessed using this digital twin, as some people might not want the turbines built so close to the offshore monument. The placement of the turbines in a location that will not interfere with offshore activity can also be aided by additional tracking data from the offshore boats.

In this instance, we are simply utilizing the necessary elements from each layer. For instance, running this simulation does not require access to city building and topography data, an urban traffic mobility model, or a 5G telecommunications model. To determine the size and location of the offshore wind turbines, we solely use pertinent wind, offshore boat, and citizen feedback data. (White et al. 2021)

Buildings in the city can also be constructed with the help of the digital twin. A circular skyscraper and a structure with a spire on top are two new enormous buildings that are being proposed, as seen in the digital twin layer in Fig. 1. ("A digital twin smart city for citizen feedback - ScienceDirect") Simulations of how these structures would affect the city's sunlight may be made in the virtual layer using the sensing data that was gathered in the digital layer, such as whether they will block sunlight from current parks. The digital layer's wind and seismic data can be utilized in the construction of the new structures. The new structures may be tested against the recognized difficulties of the city, such as strong winds or being close to an earthquake fault line after a digital twin of the new structures has been produced. Buildings can be added to an online digital twin after receiving the necessary building safety certificate. (White et al. 2021)

Citizens can easily walk around the online "digital twin" and provide feedback on new urban planning and policy decisions. To provide feedback on newly proposed structures or green areas, such as parks throughout the city, citizens can fill out forms. This enables the digital twin to provide more smart city data, which can then be used to experiment and produce new knowledge that is then transmitted back into the various smart city layers.

For instance, in the green space simulation in section 5, where users might suggest new features for a new park, a children's playpen option was added even though it had not been originally offered. The online digital twin interaction diagram is shown in Fig. 3. We can see how the approach being used online and through the internet makes it simple for citizens to provide comments. The appropriate group, such as the researchers who created the urban mobility model or the city council that supplies the urban IoT data, can then receive this feedback. The city council can then utilize this information to guide its decisions about policies and urban development. The blue box identifies the primary technologies employed, and it also displays the key stakeholders for each element of the online digital twin. (White et al. 2021)

3.6.3 Experimental setup

1. Simulation software

The digital twin, a 3D FBX model that contains the first three layers of topography, buildings, and infrastructure, was loaded using Unity3D Software (Unity), version 2019.2.10f1 Personal. Using information from an experimental investigation, pedestrian mobility models were constructed in Unity to enable crowd simulations with various kinds of agents, including adult and elderly individuals (Oxley et al., 2005). To make the simulations as accurate as possible, smart city data is obtained from the Dublinked 7 website. The model can change over time and be used for transdisciplinary city modelling thanks to the twining with actual public data from an open portal (Castelli et al., 2019).

With new construction and statistics from the municipal regarding crowding or flooding, a city is always changing over time. The digital twin can test the models and predictions on previously unobserved data thanks to the feedback loop created by the new data. (White et al. 2021)

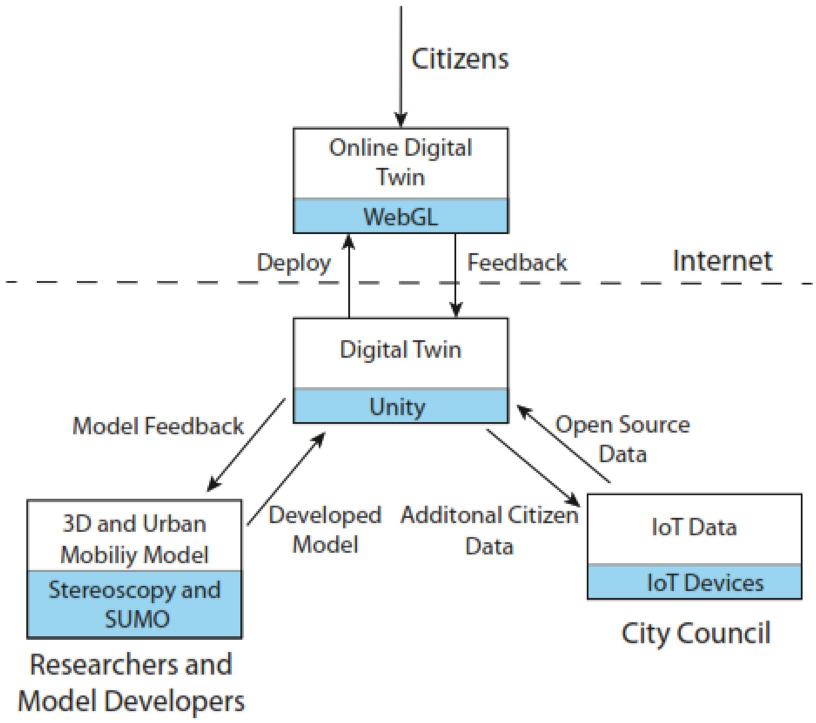


Figure 3.6 Online digital twin interaction diagram (White et al. 2021)

2. Skyline simulation

The model is also accessible online in another version. A 3D model makes it simple to remove and include freshly suggested buildings. This can help run simulations to determine how the city would react to new construction and how it would change the skyline. The BIM model makes it simple to incorporate any planned building plans into the digital twin. Using this model, residents and government representatives would be able to stroll around the digital twin and observe how the new structure will change the city's skyline from a variety of angles. Sunlight information from the smart city and the BIM file of the new building can be combined to simulate the effect that a large building will have on the access to sunlight in nearby parks or public spaces. ("A digital twin smart city for citizen feedback - ScienceDirect")

Building projects can take years to complete and are lengthy endeavours. This can result in a significant contrast between how the city seems now and how it will appear once all the ongoing construction projects are completed. To emphasize this point, in our simulation we display a current view of the model with all the finished structures in comparison to the present view in the street. To demonstrate how the skyline will change because of new construction, we will also add some more BIM models as assets to our digital twin. Citizens may be given the opportunity to provide feedback on the newly proposed building using a form in the digital twin model that is available online. Before the user can vote on whether they support the new building, it requests the user's name and email for verification. The user can provide more comments in a text box after they have voted on whether they like the new building by stating the reasons why they do or do not. (White et al. 2021)

3. Green space simulation

To promote healthy living and wellness, green space, such as parks and recreational areas, is crucial in smart cities (Anguluri & Narayanan, 2017; Lee et al., 2015). These green spaces can be developed in suitable urban areas thanks to the digital twin paradigm. Where to locate these green areas in the city can be influenced by urban planning decisions using data from the smart city, such as air pollution, noise pollution, pedestrian traffic flow, and the amount of direct sunlight. ("A digital twin smart city for citizen feedback - ScienceDirect")

It is a matter of urban planning that chooses where to locate these green spaces within the city. The smart city can be used to track the number of people who visit the new green space if the park or other open space receives approval from the local government. The digital twin can be used to simulate various park amenities like extra benches or fresh flowers, while also providing users with a range of options from which to choose or innovative ideas for improvement. Sensors in the smart city can be used to monitor the effectiveness of this modern technology. In our simulations, we increase the number of tree sites in the city and build a new park. By choosing from the following options—more benches, more summer flowers, park gym equipment, or other—citizens can provide feedback on what extra amenities they would want to see in the new park. ("A digital twin smart city for citizen feedback - ScienceDirect") The "other" option allows the user to submit a suggestion that has not been taken into consideration, which may give urban planners further insight into the needs of the local populace. (White et al. 2021)

4. User tagging simulation

It is possible to expand the first form-based simulations of the skyline and green space to let users more freely navigate the model and tag objects. Citizens would be able to tag real-world issues in the model and have the information delivered to the appropriate government department if an accurate digital twin were available. The precise position of the problem, as shown in the model, would be included in this communication.

The citizens of the city can quickly see from the digital twin in emergency scenarios which areas will be most affected by water and which highways will become inaccessible. Additionally, citizens can indicate in the digital twin where they are right now and whether they require assistance. The areas where most individuals required assistance would be recorded, which would improve the data produced by the smart city and enable more detailed simulations when employing the digital twin in the future. To make sure that the model has an accurate model for estimating the water level based on rainfall, the actual level that the water rose based on the amount of rain would also be given back into the digital twin. (White et al. 2021)

5. Flooding simulation

A digital twin's detailed 3D topography and building data are necessary for accurate flooding simulations. A 3D digital twin that has precise street elevation data can be loaded using Unity.

This makes it possible to dynamically change the water level and display the places that will be most impacted by floods caused by rivers or heavy rain.

These simulations can help urban authorities plan for floods by determining where to put sandbags and which parts of the city to evacuate first. The digital twin may be given information from the smart city regarding rainfall amounts and river levels to build a timeline of when floods can happen. The smart city can then relay this information back to the digital twin to inform residents of the timing of a potential flood. If flooding is found to be a concern for the city, the historical data gathered from the smart city can be used to develop longer-term flood protection methods. This might be for significant initiatives like creating water storage areas or changing the course of rivers. Previous methods for simulating flooding included propitiatory flooding models like Mike Flood and were primarily concerned with the financial toll that floods take (Pyatkova et al., 2019). Our strategy focuses on locating the parts of the city that are vulnerable to floods and urban mobility.(White et al. 2021)

6. Crowd simulation

Although the crowd simulation can be performed anywhere in the model, it was mostly concentrated on one intersection slightly to the north of the Samuel Beckett bridge. A general collection of spawn sites was put in the four corners of the major junction, at the entrances to the maps, and at the three arena's exits. Any of these sets can be used for a flock to set the spawn places and destinations because they are all the offspring of empty objects that describe the set. (“A digital twin smart city for citizen feedback - ScienceDirect”) The average waiting time and distance travelled were compared next between the different agent types. Elderly and adult agent types were produced in three different splits: 0-100, 25-75, and 50-50. Based on an experimental review, the elderly agents have a narrower maximum speed range, step height, and larger radius to prevent them from making sharp bends (Oxley et al., 2005). Then, their distance travelled, and average waiting times were compared.

A flocking algorithm was created for the purpose of managing pedestrian mobility. This is accomplished by giving the agents—hereafter referred to as the pedestrians—assigned behaviours. These behaviours dictate the agent's movements in relation to its surroundings and other agents. The three scripts, Flock Behaviour, Flock Agent, and Flock, make up the algorithm's core. First, all scripts for behaviour derive from Flock Behaviour, a scriptable object. The agent's next action is determined by adding the movement vectors produced by each behaviour. (White et al. 2021)

3.6.4 Results

5.1 Skyline simulation

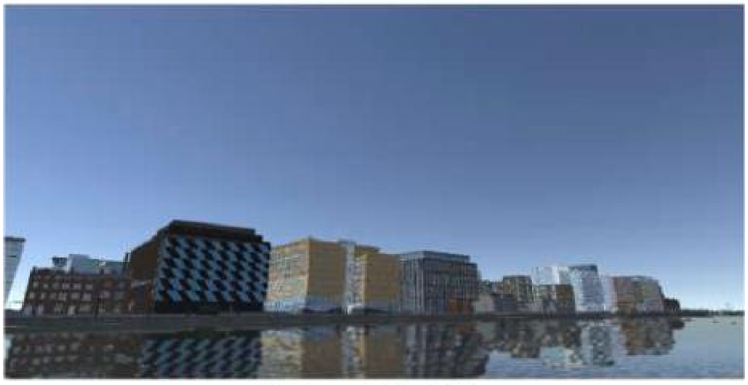
Since no in-depth technical knowledge is required, a 3D model lowers the entrance barrier for residents to participate in municipal planning decisions. Citizens can report any problems with the buildings via a 3D simulation. A comparison of the present simulated model and the Docklands' current Google Maps image may be seen in Fig. **3.4**. The current perspective in Fig. 4a and the model view in Fig. 4b clearly show a significant difference, with numerous structures still under construction in the current image.(White et al. 2021)

(a) Current Street View

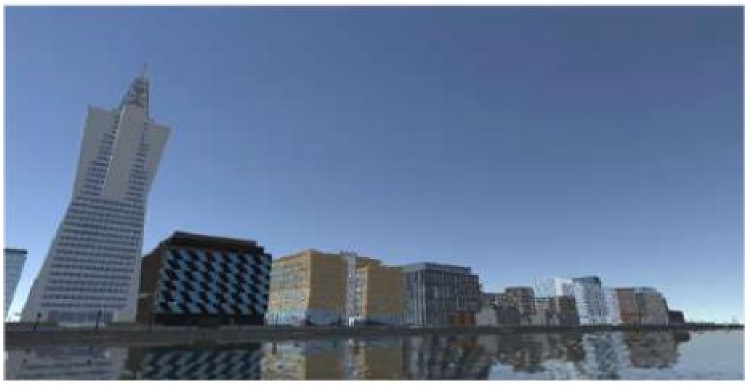
(b) Current Digital Twin

Figure 3.7 Approved building works (White et al. 2021)

Given that the construction of large structures can take years, the digital twin allows inhabitants to easily view what their city will look like in the future. A hypothetical skyscraper extension modelled after the Transamerica Pyramid that might alter Dublin's skyline is shown in Fig.3.5. The present city model is depicted in Fig.5a, and the suggested building plan is shown in Fig.5b. This makes it simple for residents and local officials to go around the area and spot any issues that a big structure like this would cause, like obstructing cell towers or sunlight. This enables any complaints to be heard prior to the start of construction.(White et al. 2021)



(a) Current Digital Twin



(b) Proposed Buiding Digital Twin

Figure 3.8 Planned buildings (White et al. 2021)

The results of an online survey that was completed by thirty residents in the neighbourhood shows that the citizens were asked if they approved of the planned new building in Fig. 3.5b. According to the statistics gathered, 78 percent of respondents approved of the new structure, while 22 percent opposed it. Citizens were then given the opportunity to explain why they approved or disapproved of the new building's design. People who were critical of the structure said that "the design didn't blend in with Dublin's architecture" and that "it is excessively tall and sticks out in comparison to nearby buildings." This can provide useful information to urban planners and policymakers to alter the building's design. (White et al. 2021)

5.2. Green space simulation

By establishing new parks or planting more trees, the Digital Twin concept can also be used to increase the amount of green space in the city. The development of new parks and other green areas in between buildings can be beneficial to cities. The creation of a park in the city's centre as a place for locals and workers to unwind is simply demonstrated. Sensors in the smart city can be used to monitor how many people are visiting the park. Because the digital twin is accessible online, people can interact with it and leave input, including suggestions for the location of additional benches, trees, plants, or outdoor workout equipment in parks. Monitoring user interaction with additional equipment is possible using smart city sensors. Fig. 3.6 b This represents a denser green area created by adding a few more trees to the city. Simulations using smart city data can be used to ensure that trees have access to adequate sunlight, temperature, and water throughout the year.(White et al. 2021)

Locals can also comment by selecting a tree from the list of trees that are eligible for the site. Fig 3.7. These findings provide feedback on additional features that should be included in the future park. Three possibilities were suggested: more park benches, more summer flowers, and park sports equipment. The second most popular option was another extruded option for child play that was suggested by a form user and then added as an option. This encourages citizen participation because they can see that options are being improved in response to their feedback.(White et al. 2021)

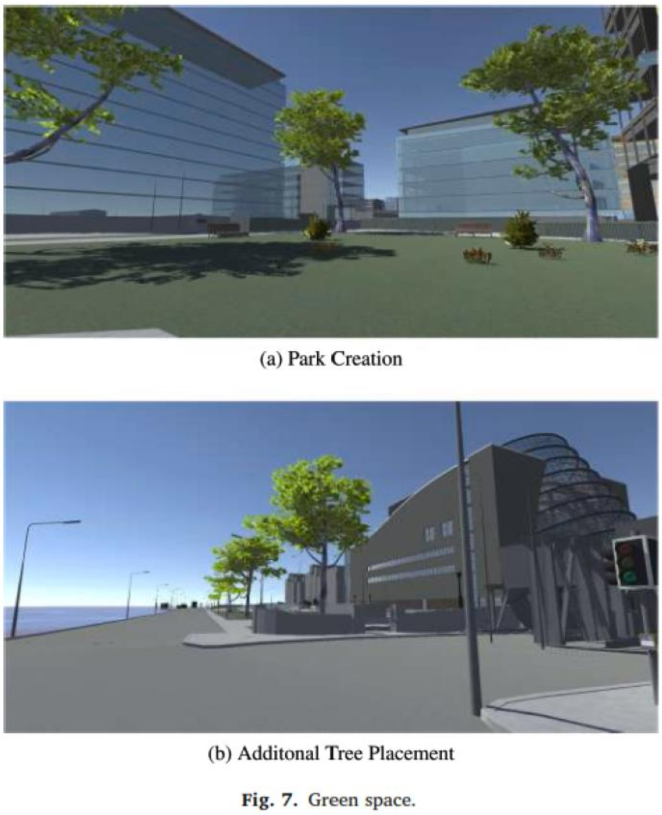


Figure 3.9 Green space (White et al. 2021)

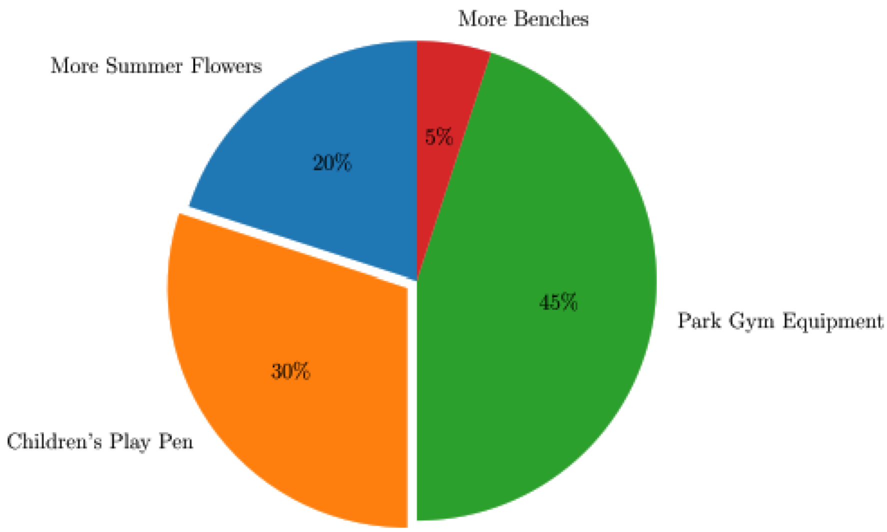


Figure 3.10 Green space simulation feedback (White et al. 2021)

5.3. User tagging simulation

Users can interact with and report objects in the scene thanks to the availability of a 3D model. Fig 3.8 illustrates a person using a streetlight in a 3D model. When interacting with the streetlight, the user has the option to report a problem, such as a broken lamp or a light that turns on while it is still sunny outside. A detailed report detailing the precise location and issue that needs to be rectified can then be sent with this report to the city council. Residents engage with a variety of various environmental elements and report issues including rubbish, antisocial behaviour, traffic jams, graffiti, and errors in the digital twin that need to be re-scanned. This enables the quick creation of extra smart city data that can be used to pinpoint the issues that residents report the most frequently.

Figure 3.11 User reporting problem (White et al. 2021)

The user tagging input gathered during the experiment is displayed in Fig. 3.9. As we can see, several user tags have been added to the map's upper left corner to report issues with litter in this area. The Dublin litter wardens and environmental health officials can then be informed of this, together with the precise location of the problem. The issue can then be resolved in that region with preventative measures like additional CCTV or the deployment of litter wardens. The map also shows some of the other places where issues were identified in the model. These were for issues like broken lights and potholes on the road. Both issues can be reported to the appropriate department along with the precise location of the issue. The information can be kept for an extended period so that a thorough analysis can be done over time to determine how council resources are allocated to various regions and which issues or locations are frequently flagged.

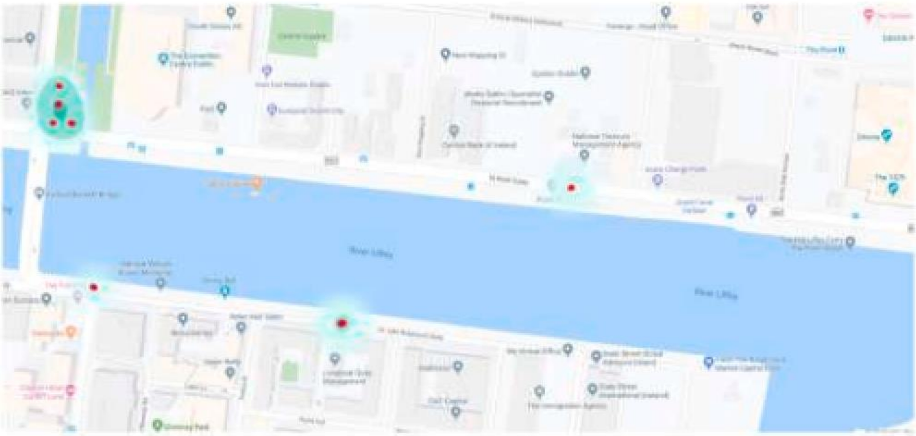


Figure 3.12 User tagging feedback (White et al. 2021)

5.4. Flooding simulation

Due to their ability to simulate extremely unusual situations, digital twins are also incredibly helpful in emergency simulations. The Dockland's flooding scenario is simulated in Fig. 3.10. The models can demonstrate how an increase in the river Liffey's water level would spill onto the nearby streets. Fig. 11a–f shows how each area in the city centre will suffer harm because of the rising water level. Sandbags and other flood defences might be strategically placed using this knowledge to protect those in the region who are most vulnerable.

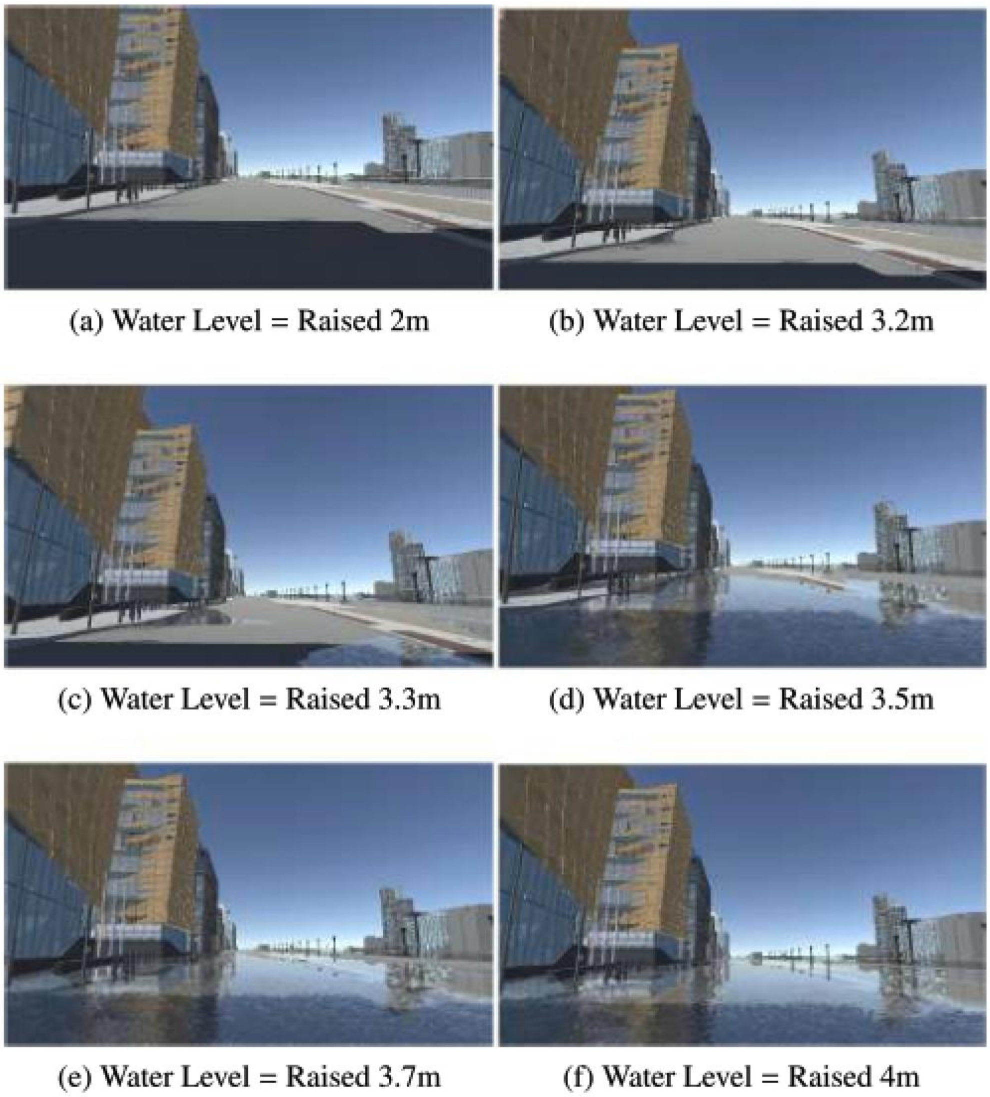


Figure 3.13 Flooding simulation (White et al. 2021)

Effective urban evacuation can also be accomplished with this flooding knowledge. Urban planners can predict how high the water will go based on the predicted rain (Alvisi et al., 2006). By doing so, they will be able to determine which locations are most at risk and start evacuating residents of those places first. Urban officials can predict how long it will take for the water level to increase by that amount, so they will have an idea of when to evacuate these people. The flooding model can then be assessed during periods of flooding. The model can be made more sophisticated by including currents, materials in the riverbed, sewage systems, and drainage networks. The objective is to establish an open model that can be coupled with other digital twin simulations, such as crowd simulations, and can be incrementally enhanced with new data. ("A digital twin smart city for citizen feedback - ScienceDirect")

5.5 Crowd simulation

In the Unity model, the crowd simulations generate two diverse types of pedestrians: an Elderly agent and a regular adult agent. We compared the two types of typical wait times, trip distances, and simulation time. Figures 3.11 and 12 indicate the typical wait time and distance, respectively. As the proportion of elderly in the simulation rises, there are not many differences in the average wait times for adults and the elderly in Fig. 3.11. The elderly agents have a significantly longer waiting period, which is a discernible difference between the two agent kinds. This is because older agents can take longer to makeover around barriers and pass-through traffic lights due to their decreased mobility and movement speed. Additional testing can assess how certain pieces of street furniture, such as rubbish, lights, and pathway width, affect how long different pedestrian types must wait while navigating the city. These simulations' findings can subsequently be used in urban planning and policy.

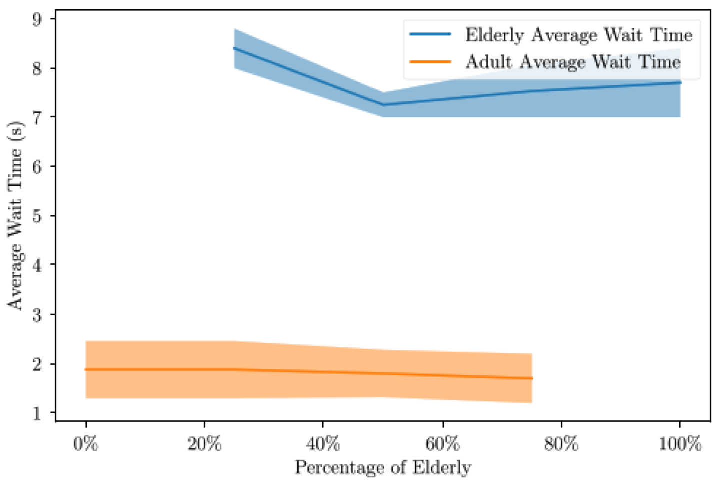


Figure 3.14 Average waiting time of the agents vs. the percentage of the flock that is of the elderly type (White et al. 2021)

The average distance covered by the various agent kinds is depicted in Fig.3.12. The senior agents' travel distance stays quite constant. However, as the proportion of old agents in the simulation rises, so does the distance travel by adults. This implies that the adult agents can go around any senior simulation players or impediments by using their higher speed. Because of this, even while the number of old persons rises with the distance they travel, their average waiting time remains low, as illustrated in Fig.3.11.

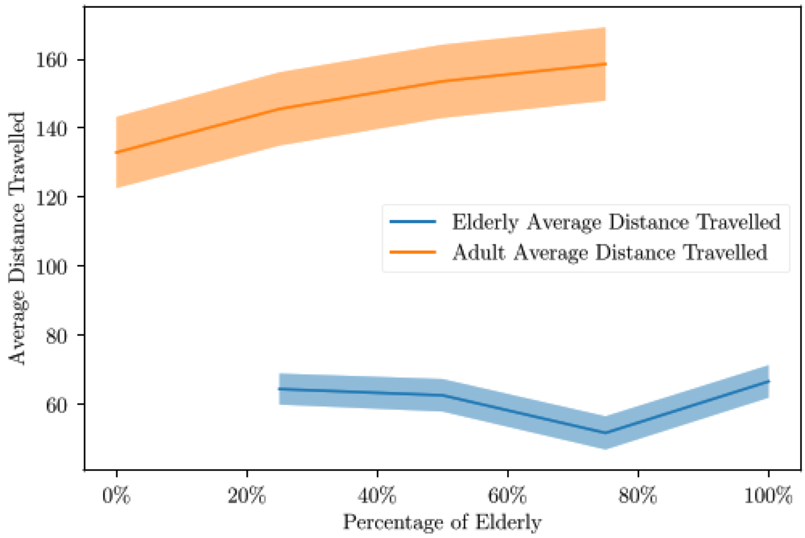


Figure 3.15 Average distance travelled by the agents vs. the percentage of the flock that is of the elderly type (White et al. 2021)

6. Limitations of current digital twin

6.1. Buildings

A sizable portion of Dublin is included in the Docklands model, and some of the contemporary structures along the waterfront are extremely well-reproduced. Grey boxes are used to depict various places in the model, particularly those with older structures and open areas. The functionality of the citizen feedback or crowd simulations is unaffected by the grey box's function, even though it cannot be inferred from the model.

6.2. Infrastructure

Figure 3.13 depicts the Riley Bridge near the Samuel Beckett Bridge, both in the real world and in its digital space. The real and virtual left sides of the bridge are compared in Figures 3.13a and 3.13c. The virtual display of the pedestrian path is smaller than its physical counterpart. In addition, the bridge has pedestals that protrude and cover the sidewalk in the model. To further realize the simulations, Unity was used to change the dimensions of the footpath and the position of the bridge. The right side of the bridge is shown in Figure 3.13b in the real world and Figure 3.13 d in the digital twin. The little bridge that allows pedestrian access on this side of the bridge is absent from the digital twin and may be seen in Fig. 3.13b. To enable more precise pedestrian simulations, a tiny bridge structure like that in Fig. 3.13 d is made in Unity.

6.3. Mobility

Some urban transportation systems are not represented in the model. For instance, the model does not account for Dublin's Luas light rail system. With the advent of this light rail system, it would be possible to compare a variety of urban transportation systems and run more thorough simulations of urban mobility. The model is also deficient in bus stations and road markings, although Open Street Map can be used to add these details.

6.4. Smart city

The digital twin's precise simulations are powered by data generated by the smart city. Through the Dublinked 9 open data sources, Dublin makes a lot of data accessible. This gives access to a variety of data sources on the population, infrastructure, and transportation, as well as details on the environment and energy. Fine-grain data, which is frequently pooled, is lacking, nonetheless. This might require the interpolation of datasets, which makes simulations less precise.

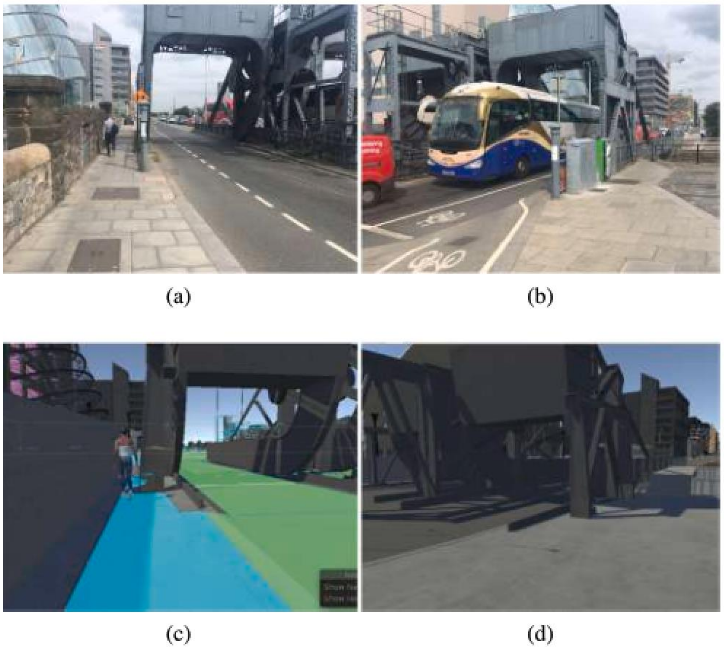


Figure 3.16 Rail bridge that has pedestrian pathways to either side of it, but cannot be passed in 3D model (White et al. 2021)

3.7 A City Planning Perspective

The proportion of the world's population living in cities is quickly expanding, from 54 percent in 2014 to over 80 percent by 2050. (United Nations 2014). As a result, municipal decision-makers must evaluate how to maintain the crucial link between individuals, infrastructure, and technologies required for city operation. (Ham et al. 2020)

Applications for emergency response management, for instance, have been discussed since the 1990s when VR was first used for city operations and was recognized as a potential tool for an early model of the Los Angeles region (Jepson et al., 2000). Rescue teams in an emergency are under pressure to act quickly and wisely with little time to process critical 3D information about structures, the placement of combustibles, subsurface utilities, or overhead landing patterns.

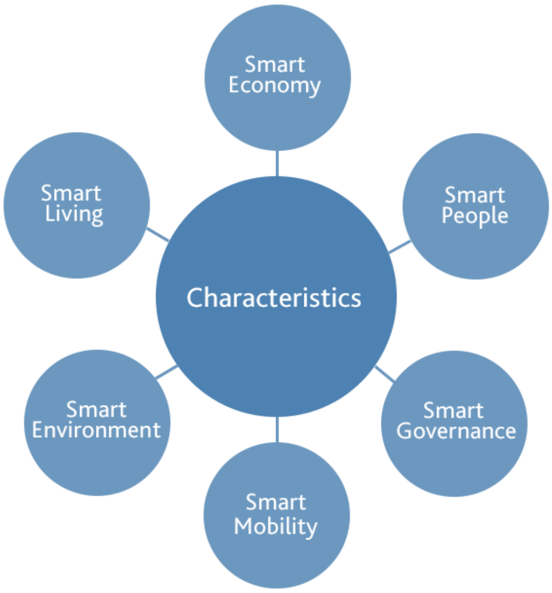
Professionals simply need to be able to "see it" in such situations, or as one consultant put it:

"You don't just need the data you need to picture this entire thing because you need to send the correct staff with the right equipment for their safety, as well as the protection of the neighbourhood." (Whyte and Nikoli 2018)

According to Albino et al. (2013), during the past 20 years, cities have become smarter because of the widespread use of information and communication technology (ICT) to track city activity (Neirotti et al., 2014). Then, data can be produced from a wide range of municipal operations, including traffic and transportation (Menouar et al., 2017), power generation (Oldenbroek et al., 2017), utility provisioning (S'anchez et al., 2013), water supply (Parra et al., 2015), and terrible management (Medvedev et al., 2015). The transportation, environment, living standards, and government of the city can all be improved by smart cities using this data. (White et al. 2021)

Decision-makers face numerous problems because of rising urbanization, and they need to be more strategic in their responses. To support efficient decision-making in complex city systems, many cities are rapidly integrating technical advancements for a data-driven approach. Recently, several cities have begun to develop and use a digital representation of a real metropolis that exists at the nexus of reality and virtuality (Mohammadi and Taylor 2017). Actual-time data using sensors like Internet of Things (IoT) devices to bridge between the real world and its virtual counterpart and analyse relationships among essentials is a significant feature of this modern technology.(Ham et al. 2020)

The sheer volume of data that needs to be gathered and processed might be overwhelming when creating smart, sustainable cities. The Vienna University of Technology established the European Smart City Model, which outlines six essential components of a smart city:



Large-scale city planning involves a considerable number of professions, including clients, politicians, policy makers, planners, communities, and individuals. All these experts need to understand this "big data."

The debate surrounding this enormous data now takes place in 2D because it is built-in in 2D. Paper maps, colour coding, detailed descriptions, and business jargon all contribute to the confusion that the public experiences. It might be entirely inaccessible. Even though 3D modelling occasionally has a role, top-down designs nevertheless serve the primary function. Non-technical stakeholders must use a lot of "imagination" to fully comprehend what is being offered, and it is debatable if planners always understand what they are proposing. (Gowling WLG 2019)

3.8 Conclusion

In conclusion, with an overview of the previous chapter, we analysed the history and background of virtual cities to see their advantages and disadvantages in urban design. Many cities throughout the world are constructing or considering developing virtual city models. While significant research has been done on the many technology solutions that potentially support virtual city models, less has been done on their long-term viability and management.

From studying the history of virtual reality, **the life span of virtual city projects is short due to technological changes**. Also, cities that **profess to follow more than one model exist.**

The concept of virtual cities is presented in **three diverse ways**: The first of them is that a **digital city is a representation of a physical city**. Second, **a digital city is one with modern information and communication infrastructure**, and finally, the term "virtual city" can refer **to systems that employ the city paradigm, such as virtual communities for collaboration and participation.** The digital city is linked to the physical city in the same way that suburbs are related to cities.

Likewise, an increasing number of studies show that knowledge of the physical city may be used to design digital cities, **which either connect the real and virtual worlds or build virtual cities for digital populations.**

Moreover, we investigate the case study of Newcastle Gateshead, which is maintained and used for different purposes. The project's goal is to find ways to build an interactive representation. The advantage, in this case, is the ability to access and share the data in VNG with other users, which will support the lifespan model.

Also, deciding on technical alternatives, collecting data, integrating with current geographic systems, developing standards and protocols, and hosting intellectual property are all part of the process of creating a virtual city.

Digital twins can be used to simulate urban planning and policy choices using the data produced by smart cities. Real-time data gathered from preinstalled Internet of Things (IoT) sensors (such as traffic, energy use, air pollution, and water quality) has been used to evaluate one of the benefits of a digital twin city for managing intricate city systems. ("Participatory Sensing and Digital Twin City: Updating Virtual City ...")

By using the digital twin, it is possible to **involve the public and gather a variety of informed feedback on crucial policy and urban planning issues**. These simulations can be expanded to analyse **potential options for urban planning in a smart city**. Virtual Singapore has a 3D urban model (3D) and a data platform as an image of the digital urban twin that is still in development.

The results of a variety of simulations that may be run utilizing a digital twin of a smart city are demonstrated in the results section. The outcomes of these simulations can be fed back through the digital twin model's layers to suggest actual modifications for a smart city.

Chapter 4: Digital Citizen & User experiences in Virtual reality environment

4.1 Cities & digital society

Cities have always been about connecting people. Cities exist to connect people who live in communities. Infrastructure has always supplied the web of links that community life requires. The physical environment was the original infrastructure of cities: trails, roads, streets, marketplaces, meeting places, and city walls. The physical environment has traditionally served as a medium of communication in the sense that cities and their infrastructure are about connecting people. (Ishida 2000)

Cities are the settings for ongoing, innovative interventions that are influenced by socioeconomic, demographic, political, and cultural factors. Cities are consequently multidimensional and complicated, which makes it clear that there is no single "urban reality" and that numerous urban images, mappings, or perceptions of the city coexist in the minds of urban planners, designers, and citizens, as Calvino eloquently describes in his Invisible Cities.(Fernandez-Maldonado and Ana Maria 2005)

The concept of a "digital society" captures how modern society has adopted and integrated information and communication technology at home, at work, in the classroom, and during leisure time.(LIBRE n.d.)

With a size and speed unlike anything else, digital breakthroughs are altering our society, economy, and industries. The Internet of Things, Big Data, and mobile and cloud technologies provide unfathomable prospects for growth, improving the lives of residents, and increasing efficiency in a variety of sectors, including public administration, health care, transportation, energy, agriculture, manufacturing, and retail. By assisting decision-makers in making better choices and involving citizens, they can also enhance the governance process. The Internet has a lot of potentials to advance human rights, including freedom of expression and access to information, as well as democracy and cultural diversity. (LIBRE n.d.)

However, we also need to comprehend how these changes' scope and speed affect users, citizens, workers, and everyone else who makes up a "digital person," as well as how they impact business, government, democracy, education, and other spheres of public and private life. (LIBRE n.d.)

The new digital domain, often known as cyberspace, is a virtual environment made feasible by several digital technologies rather than being a technology or infrastructure in and of itself. It is creating a whole new variety of urban possibilities, combining the virtual and physical worlds with its abilities to design numerous, dynamic realities with deeply entrenched spatial metaphors.(Fernandez-Maldonado and Ana Maria 2005)

The digital infrastructure of computer hardware, software, high-speed telecommunications networks, and the human minds that created and used these technologies make up the digital infrastructure of cyberspace, which consists of the abstract and intangible spaces of information and communications flows (Dodge and Kitchin,2001). People are continuously altering the virtual environment. What we can get from a virtual world is what people have put into it.(Fernandez-Maldonado and Ana Maria 2005)

The Internet and the Web, unlike previous technologies, are media that are mostly produced by software and made user-programmable (Dodge and Kitchen, 2001). Professional operators may produce content and provide services locally or globally, but since Internet technology is built on an open protocol, anyone with basic technical knowledge can be present in cyberspace and use Internet applications to their advantage. The result is that the Internet is a serious technology that will have unintended social consequences due to its high adaptability and high sensitivity to human adaptation.(Fernandez-Maldonado and Ana Maria 2005)

As soon as people were aware of the characteristics of the Internet technical architecture, they began to see it "as a model for a truly anarchic society where knowledge is freely distributed, control and regulation are hard to exercise when there is no hierarchy" (Bell, 1994; as cited in Aurigi and Graham, 1997).(Fernandez-Maldonado and Ana Maria 2005)

Modern technology can solve urban problems and provide fresh solutions, which is something those urban planners and other professionals should try to recognize. It becomes vital to critically assess the part that ICTs play in the modern metropolis. (Fernandez-Maldonado and Ana Maria 2005)

Numerous ICT policies and initiatives are now being implemented in the Western world to combat urban poverty and social exclusion, enhance the urban economy, and support urban administration. The initiatives started by local governments, activists, and/or groups of civil society to provide online services in a particular locality are understood through the concept of virtual cities.(Fernandez-Maldonado and Ana Maria 2005)

The physical infrastructure that supports virtual cities' presence, their virtual or online representation, and their users are all necessary factors that must be considered to get a picture of their status in cyberspace. However, as the empirical studies demonstrate, there are a wide variety of variations in the objectives, designs, and organizational structures of virtual cities. The distinctions are connected to the various social situations in which they are developed and sustained. (Fernandez-Maldonado and Ana Maria 2005)

4.2 Representation in virtual world (2D and 3D models)

Representations are developed to be meaningful abstractions of objects or concepts (Scaife and Rogers, 1996). We use the term representation to refer to a variety of abstractions in design and construction, ranging from the most abstract diagrams and sketches to more photo-realistic pictures and models. (Otto, 2002). Virtual reality models, for example, show a basic lack of absolute connection between their representations and the objects they display. (Whyte and Nikoli 2018)

A representation is "its structural equivalent in a specific medium," not a reproduction of what is represented (Arnheim, 1954: 162). This means that to build a particular representation, decisions must be taken regarding what to include and what to leave out. For example, digital city models frequently do not depict graffiti, litter, or weather conditions found in real cities, instead focusing on urban shape. In addition, our interpretation of any representation is influenced by our prior knowledge, abilities, strategies, and motives (Chen and Stanney, 1999). (Whyte and Nikoli 2018)

Representations can have distinct advantages and disadvantages for different tasks and users depending on the shape they take. Items in the built world, for example, can be represented in an iconic way, with representations that closely resemble the objects that they relate to. Alternatively, objects might be represented symbolically, requiring the user to learn a 'code' to comprehend certain elements of the representation. Photographs, digital models, and highly photorealistic renderings are examples of iconic representations of the built environment, while sketches, maps, and diagrams are frequent symbolic representations. (Whyte and Nikoli 2018)

While most VR applications show highly realistic images, practitioners and researchers are working on tools and strategies for employing VR in more abstract and symbolic ways or changing iconic images with symbolic images. Greater abstraction, for example, in the initial stages of design, may provide viewers more leeway to examine and interpret what they see by reducing visual clutter (Radford et al., 1997). A simple plan may support a highly realistic first-person or viewer-centred viewpoint in other applications, such as exploring a building.(Whyte and Nikoli 2018)

4.2.1 2D representation

The use of two-dimensional (2D) representations, such as maps and plans, to simplify three-dimensional (3D) phonemes is common. By translating these phenomena into 2D, we can describe environments that are too massive and complicated to be seen directly (Macheachren, 1995). Furthermore, from a single perspective point, 2D representations can present whole environments. The ability to view the world at different scales allows us to prioritize the structures that are most visible at these scales and shifting our attention between scales can help us focus on certain parts of the built environment. However, the medium in which spatial knowledge is represented can have an impact on user comprehension. "To see a map is not to stare out of some imaginary window, but to observe the world in a detailed style," one researcher explained (Hender son, 1999: 28). (Whyte and Nikoli 2018)

Rather than providing direct access to a phenomenon, a 2D representation provides an interpretation or description of it. Designers may consciously utilize media like sketches, which are easy to question, edit, or erase, or produce 2D representations like elaborate computer blueprints, which are more difficult to ask questions about and change.(Whyte and Nikoli 2018)

4.2.2 3D models

Design and construction experts and non-professionals can better understand spatial features of existing and proposed built environment projects using three-dimensional representations or models. Models can be physical (size models) or digital (computer models). Professional tools like BIM are model-based, and the usage of digital models in the design of built environment projects is becoming standard industry practice. When using BIM, 3D models and other project information are often created first, and unlike traditional design methods, 2D drawings are generated from these models. Digital models viewed on 2D screen systems, on the other hand, are seen as perspective, axonometric, or isometric representations on single or multiple 2D viewing planes due to the features of screen technologies. In other words, even though these models are developed in 3D environments and may be viewed in stereo, most users interact with and view them on 2D screens.(Whyte and Nikoli 2018)

4.3 Perception in virtual environment

Different psychologists have different perspectives on how human cognition and perception are related. Some people's brains reorganize images like 2D drawings and 3D models into mental representations. Both intended and unintended aspects set the virtual reality experience apart from the real world. Such shortcomings may be more problematic for mixed and augmented reality applications, in which virtual images are overlaid on real-world scenes (Drastic and Milgram, 1996). As a result, the conception of both a virtual and a real-world is crucial to the experience. Viewers can frequently quickly adjust to improperly calibrated systems, such as a viewpoint that is too high for the user or distorts an image, while completely engaged in a VR world.(Whyte and Nikoli 2018)

Visual perception, however, only contributes to a portion of how we perceive the constructed environment. The interaction of our senses, which provide us with sight, smell, touch, balance, and orientation, allows the human body to experience its surroundings. Our brains process information from various sensory systems to provide us with constant spatial orientation so we can coordinate our bodies and emotions. For instance, it is well known that motion sickness can result from a discrepancy between our visual sense, which detects motion in a virtual environment, and our locomotive system, which perceives the body as immobile. A recent VR study also hints that our emotional state may be influenced by how we perceive our environment and body. As a result of the sometimes-disorienting physiological nature of navigating virtual surroundings, users can experience anxiety and happiness simultaneously.(Whyte and Nikoli 2018)

4.3.1 Interactive experience

VR environments differ from the 2D, and 3D representations mentioned before in that they are more interactive, spatial, and social in nature. Virtual worlds differ from animations and 3D movies in terms of the level of involvement they enable. Users in VR systems have more freedom to move around and decide what they want to observe inside an environment because they are not limited to fixed viewpoints. In addition, users in a VR environment may be able to alter the environment's characteristics or add things to it using tools or gestures in addition to the usual navigational abilities. (Whyte and Nikoli 2018)

People often engage with virtual surroundings naturally and are aware of the consequences of their choices, much like in the real world. However, interacting with a virtual environment frequently differs from doing so in a physical one. As navigating a virtual environment is often not confined to the transit modalities we encounter moving through the real world, our perceptions of time and distance in a VR model frequently differ from our real-world experiences. Also, users may be able to fly, jump, and move quickly through the environment in virtual reality, in contrast to the real world, where a realistic walking speed may feel slow. In a virtual model, moving between two points can frequently be accomplished more quickly than in the real world. (Whyte and Nikoli 2018)

On mobile computing devices, there are currently simple applications that enable interaction with basic VR models, and for users who have access to more advanced VR facilities, greater realism and interaction are feasible. However, because body movements in VR settings typically tend to be restricted and distorted, exploring a virtual environment can sometimes be challenging and constricted. Because our bodies do not move within a model, but the virtual world moves in relation to us, the user experience in some immersive VR apps is typically disembodied.(Whyte and Nikoli 2018)

4.3.2 Spatial Experience

The spatial aspect of VR in built environment applications also has significant drawbacks. For instance, on small displays, we tend to perceive places as being smaller than they are, therefore game creators make rooms that are too big. Professionals in the built environment are unable to alter the scale of the real world in their models, thus careful spatial experience design is required to create realism. Additionally, the decision about a VR interface frequently depends on the work at hand. For instance, VR users may have the option to shorten the amount of time needed to walk through a city model. Depending on the work, it may be acceptable that the physical movements necessary to move through the model differ noticeably from equivalent ones in the real world. (Whyte and Nikoli 2018)

4.4 Shaping user experience

In the first chapter, we discussed how the purpose of VR systems is to give immersive and intuitively interactive experiences of simulated environments or to embed people "within" a virtual world. "Presence is a distinguishing aspect of the virtual reality experience, and it refers to the sensation of being "within" a virtual world or viewing virtual items as "real." (Whyte and Nikoli 2018)

Establishing a sensation of presence has been described as creating "an illusion that a mediated experience is not mediated," whether a user is perceptually and psychologically totally 'inside' a simulated world or viewing virtual information overlaid on real-world visuals (Lombard and

Ditton, 1997). As a result, the qualities of a VR medium and its users dictate its presence in most cases.(Whyte and Nikoli 2018)

User motivation should increase with immersion, and pervasive virtual environments should provide a positive user experience (UX). When we interact with a simulation in a virtual reality setting, we tend to focus on the simulation rather than the technology that enables it. As a result, VR users are more likely to concentrate on the depicted data and the tasks at hand, such as assessing construction safety measures. In other words, we usually become aware of VR technology only when it fails to perform as expected. (Whyte and Nikoli 2018)

4.5 Social interaction in digital cities

Virtual reality, of course, cannot be taken for reality, as it hides or modifies physical reality in several ways. By examining user behaviour in virtual worlds, researchers have learned a lot about human perception and cognition (e.g., Diemer et al., 2015) and social interaction (e.g., Schroeder et al., 2001). Some of the findings are counterintuitive, implying a complex interaction between people and their surroundings. Drawing on the literature, we address representation and perception in virtual environments and offer VR as an interactive, spatial, and social experience. (Whyte and Nikoli 2018)

Recent research has also been done on the social experience of using VR, highlighting the threshold spaces involved in navigating an immersive environment as well as social practices, like changing shoes, which have become common in the use of large-scale collaborative VR environments. These studies are drawing on a related sociological tradition (Maffei and Harty, 2015). There has been a lot of interest lately in using VR for experiential learning, or learning by doing and reflecting on it, especially through comparisons of how experienced practitioners and lay users interpret virtual settings. Any given VR model's success is dependent on the work at hand, the model itself, its users, and the environment in which it is used. (Whyte and Nikoli 2018)

Using VR, we can enter circumstances that would be otherwise impossible to re-enact in the classroom, such as visiting Machu Picchu, doing surgery, or conducting a science experiment without the necessary tools. Since learning by doing is the best way for us to remember information, virtual reality is a terrific tool to advance education globally.(Pennington 2022)

In 2019, Neurons Inc. was hired by Facebook to conduct a study comparing how people behaved when chatting to a stranger in a virtual reality environment to a typical in-person interaction. One of the main questions of the study regarding whether social interaction in VR would feel strange and unnatural or whether novice users would enjoy it was answered. And what they found out is surprising. They found that VR conversations produced the same level of emotional engagement as in-person talks. This suggests that VR, while still being a modern technology, is an improvement for social interaction compared to existing forms of tech-mediated social interaction. (Neurons 2020)

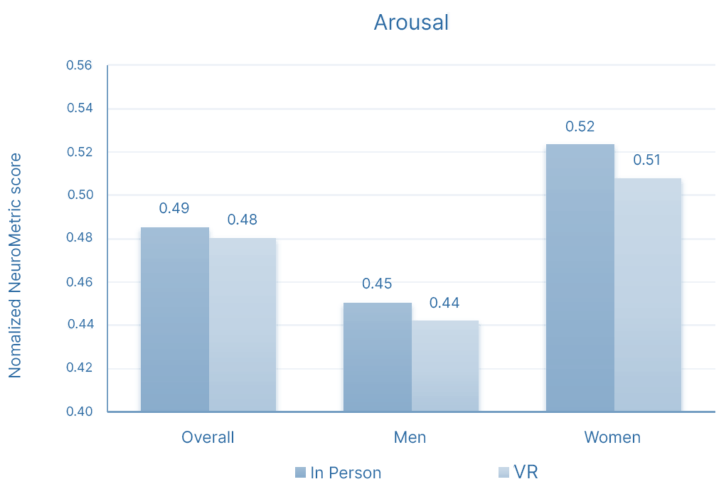


Figure 4.1: Arousal difference between in person and VR (Neurons 2020)

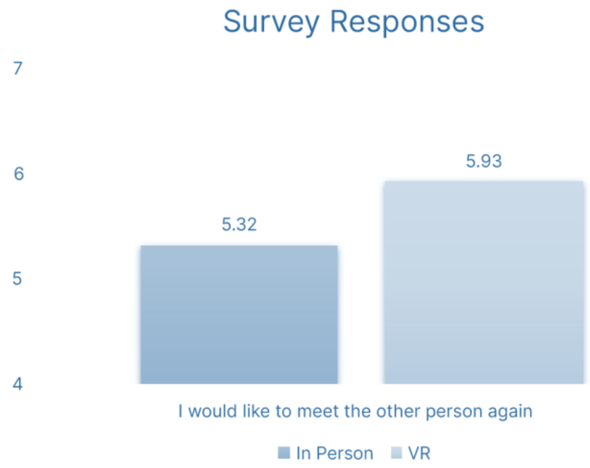


Figure 4.2 Survey responses (Neurons 2020)

Another discovery they made was that the cognitive demands of VR chats were comparable to those of in-person conversations. To put this into perspective, earlier research at Neurons discovered that video chats can be too mentally challenging. In fact, they have discovered that video chat levels can exhibit high cognitive loads that are greater than the ideal "sweet spot" values and are considered cognitively taxing. This is especially significant for women because they exhibit a higher level of cognitive stress during a video conversation.

Another surprising outcome was that people who were more generally introverted liked the VR chat over in-person conversations and were also more emotionally engaged in it. (Neurons 2020)

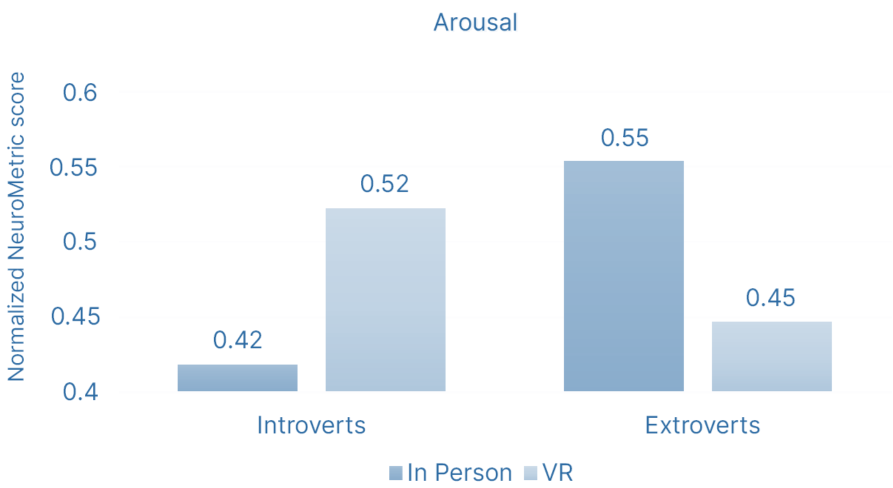


Figure 4.3 The Arousal between introverts and extroverts (Neurons 2020)

4.5.1 The Psycho-Social Infrastructure: Digital Cities and Human Needs

There are fundamental human needs associated with connection and disconnection. Individuals are motivated to develop and maintain relationships by social needs, according to a popular social scientific notion expressed in William Schutz's work [19]. Specifically, the three interpersonal needs are: inclusion, affection, and control. Control is the need to make decisions and take responsibility or the willingness to abandon such responsibility and consent to others' decisions: attachment, the need to be loved and accepted by others, or the willingness to love and accept others. (Ishida 2000)

It is claimed that each social need has specific levels, hence the degree and influence of a particular need on participatory patterns varies from person to person. Each need's importance fluctuates over time. A large body of research implies that these demands exist and are important, with some claiming that these three social needs are linked to most interpersonal conduct. (Ishida 2000)

People build their life so that they can include others and participate in their activities. This goal can often be attained by sharing a social environment. The essence of community participation is inclusion and social attachment. The desire to belong to a group satisfies this need. "Common," "communication," and "community" are all connected ideas.(Ishida 2000)

"Community" is the clear connection between "common" and "communication." According to social exchange theory, a cost-benefit analysis can explain the level of community engagement (physical or virtual, face-to-face, or digital). Control, or a person's need to oversee a situation, leads to a desire to connect or, on occasion, to disengage. Fear or insecurity that arises when one cannot manage a situation in which the individual's demand for control is strong triggers control tactics. Individuals can control their connections at home and at work, and they can use media technology to isolate themselves while they are out in public. (Ishida 2000)

However, a lack of control, fear, or insecurity may lead to avoidance of the situation or dissociation from other people and the social environment, which are related to an uncomfortable level of control. Disconnection is fuelled by control. We become more isolated the more we widen our connection. The more we have control over our communication environment, the less surprise or chance we will encounter daily. The more we connect, the more we want to be in control of it. We become more reliant on environmental surveillance as we become more detached from our local surroundings. We have less faith in the information we receive when there are more communication options available. The more data and information we have, the more we require. We desire more communities as we gain greater individualism. (Ishida 2000)

4.6 Digital generations: The effect of virtual environment on different generations

There is no avoiding the fact that different generations use technology in diverse ways. As they have never experienced the world some other way, younger generations are more accustomed to using technology. They grew up in the digital age. Because they must adjust to them, older generations can be more unwilling to participate in online activities. They are immigrants from the digital world. (Both titles are older than 20 years, which is a fun fact.) We will examine these technological differences between digital generations in this article to learn more about how each group now uses technology, potential cybersecurity risks they may encounter, and how to keep secure online at any age. (Chivers 2021)

4.6.1 An overview of digital generations

Which digital generations are there? It can be viewed from a variety of angles. A generation that was born into or grew up in the digital era, that is, with widespread access to modern facilities like smartphones, tablets, computers, and digital information like the internet, is referred to as the "digital generation" in a unique sense.

The phrase "digital generation" has also been used to describe an NPR series that examines how various communities and generations use technology.

But for this overview, we favour the perspective that any individual alive today can be regarded as a member of the digital generation since, regardless of how often we use technology, we live in a digital-first environment. Just look to the following generations and when they were born:

- **Silent Traditionalists were** born between 1925–1945
- **Baby Boomers** born between 1945–1965
- **Gen X was** born between 1965–1980
- **Millennials** born between 1980–1995
- **Gen Z was** born between 1995–2010
- **Gen Alpha,** born 2010 to the present day

We can divide these generations into digital natives and digital immigrants, labels first used by Marc Prensky in 2001, based on how advanced technology was at the time each generation was born. (Chivers 2021)

Figure 4.5 Digital immigrants' representation (Chivers 2021)

4.6.1 The anatomy of a digital native

For those who were born into the digital age, there is no other world. Because they were born or raised in the digital era, which was characterized by wide internet access and the availability of technologies like computers and smartphones, they are frequently more proficient in tech languages.

Digital natives are used to responding to technological change, but it does not always indicate they are aware of the dangers posed by new developments in the internet and technology.

So, what age groups are digital natives? Millennials, Gen Z, and Gen Alpha are all regarded as digital natives because they were all born after the early 1980s when the internet was founded. (Chivers 2021)

It is important to note that Generation Z was raised in a more connected and technologically advanced society than any previous generation and that they have never known a world without mobiles. This has significant ramifications for marketing strategies aimed at Gen Z consumers. With 41% of Gen Z members having tried VR and 13% using it every day, VR technologies like Google Cardboard, the Oculus Rift, and Samsung Gear have made their way into their lives. (Q4 2016 study of three hundred Gen Z'ers by Sabre Labs: "Emerging Tech in Travel 2017″). (arvrtech 2017)

Members of the first generation, the millennials, are more interested in having experiences than accumulating more "things." According to DeYoung, Generation Z is much more interested in experiences that go beyond the brand or the product. The experience of virtual reality is evolving. In its ideal form, it allows them access to a world they might not normally visit. It links them and encourages them to delve deeply into a fresh, creative world. While Gen Z may treasure antique boots or their grandfather's bomber jacket from the Vietnam War, they also value unique and unforgettable experiences. The more memorable the experience, the more likely it is that Generation Z will tell their social networks about it.(arvrtech 2017)

Marketers must comprehend the multi-cultural and communal attitudes of Gen Z because this knowledge affects the strategies utilized to engage them. Any experience that creates a demographic silo will not be successful with Gen Z since they dislike being lumped into categories or stereotypes. According to DeYoung, there is a lot of room for creative flexibility and inspiration in the developing VR world thanks to marketers' ability to use this data to develop the ideal content experiences for these consumers. (arvrtech 2017)

More than anything else, Gen Z wants to feel like they are making a positive contribution to society. Virtual reality can place Gen Z immediately inside the settings they are most passionate about, from a distant village in a Third World country to a bee farm in Vermont, for a non-profit organization or a business that leads through corporate giving. Gen Z will long for a connection to the causes that matter to them while they are unable to personally participate in the event. Through VR, you can make just that connection. Consider what Pencils of Promise accomplished by digitally transporting contributors and other viewers to a school in Ghana, or what Haagen-Dazs did with The Extraordinary Honeybee. (arvrtech 2017)

As a result of the abundance of content experiences available to them, Generation Z is quite the content curator themselves. In comparison to their expectations of technology-focused brand encounters, the VR experience's quality must be exceptional. Focusing on the storytelling element is where marketers can succeed with VR and Gen Z given the dwindling attention spans and increased technological distractions.

Campaigners, curators, and creators are Gen Z representatives who may receive encouragement and support from their parents, teachers, and classmates. Although virtual reality is a new medium, it has the potential to inspire young people to pursue STEM-related careers, design their surroundings with greater effect and compassion, and engage with companies and their surroundings in novel ways.(arvrtech 2017)

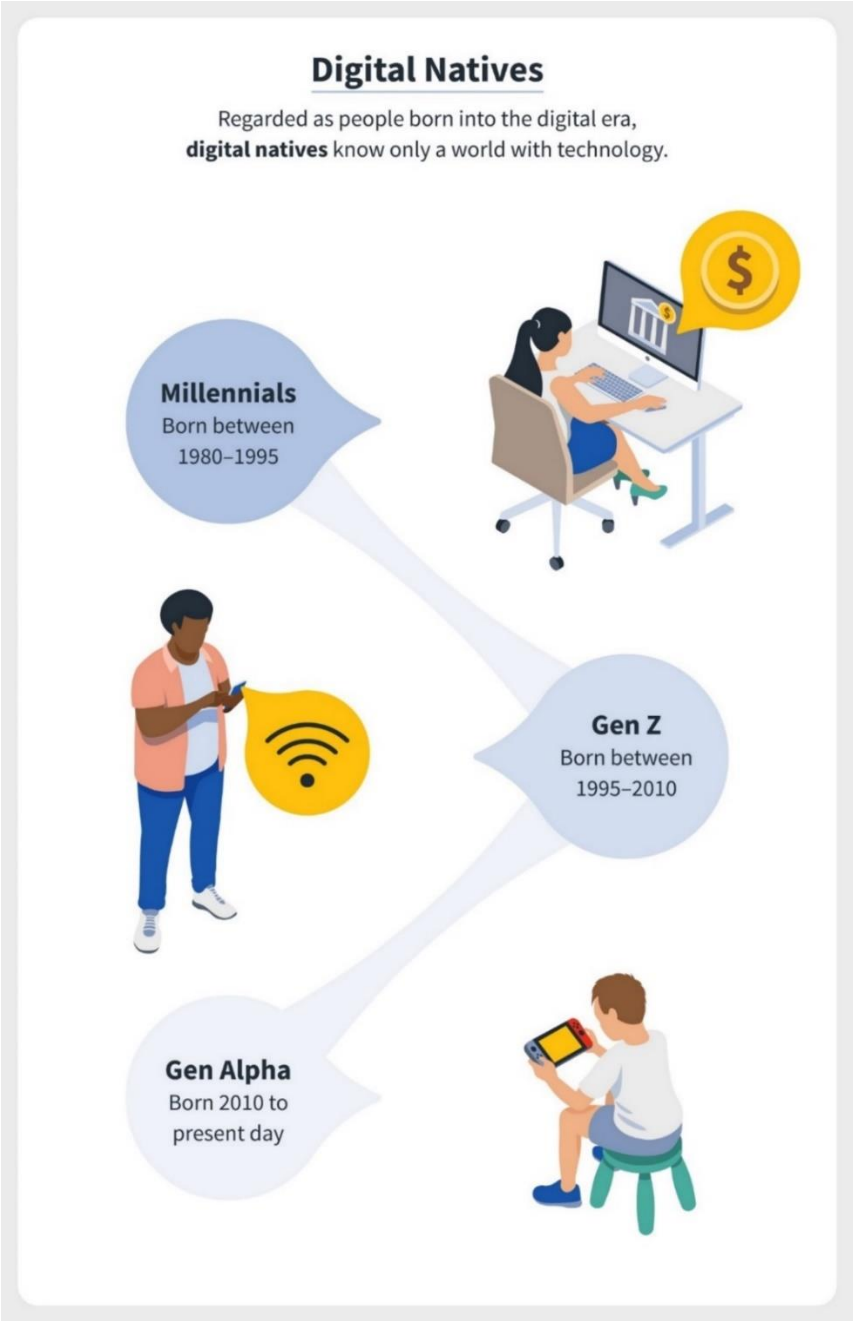


Figure 4.6 Digital natives' representation (Chivers 2021)

The anatomy of a digital immigrant

A period when the globe began to shift toward a tech-first civilization is when digital immigrants were born or grown. Gen X, Baby Boomers, and Silent Traditionalists are all seen as digital immigrants because they do recall a time before the internet began to take off.

These digital generations do not naturally incorporate technology into their daily lives. They have had to learn to adjust to the digital-first world, and sometimes they find it difficult to do so. Rather than accepting new-wave conveniences, they frequently look to more traditional answers. (Chivers 2021)

Returning to the cup of sugar scenario, digital immigrants may opt to knock on a neighbour's door before getting a whole bag online or even messaging a neighbour for a cup.

In general, digital immigrants take longer to use the internet or other connected gadgets and are less knowledgeable of how they operate in the first place, as well as the risks they pose. (Chivers 2021)

4.6.2 Potentials of virtual reality for digital immigrants

The digital divide between younger and older people may make it difficult for older people to experience the promised advantages of VR and AR in their daily lives (Cotten, 2021). For instance, although some older people can use contemporary technologies like VR and AR to sustain social connections during the current COVID-19 epidemic, these adults may also feel socially alienated when they lack the essential skills and equipment to be integrated into these digital communities (Gao et al., 2020). (Seifert et al., 2020b). (Seifert and Schlomann 2020)

The adoption of internet-connected gadgets and the expansion of internet access globally have made VR and AR more accessible to the public. However, compared to younger people, older people use the internet and mobiles less frequently (Anderson,2019). Only 53% of adults aged fifty and above accessed the internet, according to a poll conducted in Switzerland and 16 EU nations (König and Seifert, 2020). The poll found that personal characteristics like age, gender, education, income, health, and past technological experience all predicted older people's use of the internet. Additionally, a person's degree of technological socialization may have a significant impact on how they use technology. For instance, members of the Baby Boomer generation (those born between 1950 and 1969) were not raised with digital technology and were not socialized to use it. (Sackmann and Winkler, 2013). (Seifert and Schlomann 2020)

In addition, they frequently face obstacles because of their restricted cognitive, physical, financial, and social resources (Schulz et al., 2015; Mitzner et al., 2019), and they must work harder than younger people to grasp modern technology.

Many of these issues deal with the first level of the digital divide, which is concerned with access to contemporary technology like information and communications technologies and how it affects how people utilize them (Scheerder et al., 2017). The second level deals with disparities in how modern technologies are used by users, such as the digital divide between skilled or active users and nonskilled or passive users. The third level focuses on the various advantages of technological interventions (such as well-being or social inclusion) for various people. The digital divide in the context of virtual reality and augmented reality thus relates not only to having access to these technologies but also to either actively or passively using VR/AR tools in everyday life contexts and if the technologies have beneficial effects for the older person. (Seifert and Schlomann 2020)

According to our assessment, VR and AR have a lot of potential in the following five aspects of life for older adults:

1. Real world orientation:
2. Education
3. Health
4. Entertainment
5. Social interaction

Technology use statistics across digital generations

Every digital generation adjusts to these changes at their own rate because technology is constantly changing, whether its toddlers using a tablet to watch YouTube Kids or grandparents who prefer email over texting to communicate with their relatives.

We have compiled data on technology use throughout each generation to provide a clearer picture of how each digital generation fits into our current digital-first environment. For completeness, we have also added a cyber safety spin to the information to highlight some of the dangers these generations may encounter and provide solutions to assist in safeguarding their online activity. (Chivers 2021)

4.7 Conclusion

This chapter has presented the usage of the internet and virtual environments for **developing society and analysed the impact of that on social interaction.** The concept of a "**digital society**" describes how contemporary **civilization has incorporated and embraced information and communication technologies.**

Since Internet technology is built on an **open protocol**, anyone with basic technical knowledge **can be present in cyberspace and use Internet applications to their advantage**. The result is that the internet is a serious technology that will have unintended social consequences due to its high adaptability and high sensitivity to human adaptation.

Additionally, professionals in urban planning and designers should consider **how contemporary technologies are affecting cities today as well as how they might be used to address issues and provide fresh solutions.**

In addition, virtual reality users **tend to focus on represented information, as in design and construction, we use the term representation to refer to models and photorealistic images to have a more realistic representation.** Virtual reality is not the same as physical reality, although many VR systems aim to produce representational parallels to real-world settings. Representations can have distinct advantages and disadvantages for different tasks and users, depending on the shape they take. While most VR applications show highly realistic images, practitioners and researchers are working on tools and strategies for employing VR in more abstract and symbolic ways or changing iconic images with symbolic images. Representation in 2D and 3D has its benefits. For example, in 2D, we can describe environments that are too massive and complicated to be seen directly, and 3D representations or models help professionals and non-professionals more easily comprehend the spatial characteristics of current and proposed built environment projects in design and construction. However, the perception in a virtual environment between people is different, some people's brains reorganize images like 2D drawings and 3D models into mental representations.

Visual perception only contributes to a portion of how we perceive the constructed environment. The interaction of our senses, which provide us with sight, smell, touch, balance, and orientation, allows the human body to experience its surroundings. Our brains process information from various sensory systems to provide us with constant spatial orientation so we can coordinate our bodies and **emotions. VR environments differ from the 2D, and 3D representations mentioned before in that they are more interactive, spatial, and social. Users in VR systems have more freedom to move around and decide what they want to observe inside an environment because they are not limited to fixed viewpoints**. Also, users may be able to fly, jump, and move quickly through the environment in virtual reality, in contrast to the real world, where a realistic walking speed may feel slow. In a virtual model, moving between two points can frequently be accomplished more quickly than in the real world.

The social experience of using virtual reality is different between generations, genders, and career paths. Individuals are motivated to develop and maintain relationships by social needs, according to a popular social scientific notion. One of the surprise outcomes was that people who were more generally introverted liked the VR chat over in-person conversations and were also more emotionally engaged in it. **The outcome also revealed whether first-time VR users would find social contact weird and unnatural or enjoyable.** It was discovered that VR talks elicited the same level of emotional involvement as in-person conversations.

In addition, the potency of different generations for accepting and using virtual reality and technology is diverse. **Digital natives and digital immigrants are two groups based on how advanced technology was at the time each generation was born.** In general, digital immigrants take longer to use the internet or other connected gadgets and are less knowledgeable of how they operate in the first place, as well as the risks they pose.

Furthermore, older individuals have varied potential and obstacles when integrating VR/AR tools into their daily lives depending on their "actual" circumstances (such as their living or social environments). Individuals must accept, use, and gain skills connected to digital systems to access them. Researchers should be mindful of older persons' unique use preferences as well as their competencies and use levels, though, because of the digital divide between younger and older adults.

We believe that older people can benefit from the unique and innovative opportunities provided by VR and AR. These tools can help older people, their family members, and their professional caregivers live better every day. However, using technology can be difficult, particularly for older people who do not have access to modern equipment or strong digital literacy. **Developers, practitioners, and researchers in the sector must understand digital disparities and offer training materials, assistance services, and digital solutions that consider the diverse histories and requirements of older people.**

Chapter 5: Participatory Democracy

5.1 The Architecture of Democracy

People have gathered to participate in and watch democracy in action for at least 2,500 years. Humanity's relationship with the idea of democracy can be reflected in the physical surroundings where democratic discourse takes place. The right of citizens to participate in political decisions that have an impact on their daily lives is referred to as the democratic imperative.(Sudjic 2001)

Participatory design is direct democracy in action. It is based on the typical locations and lives of people. To be democratic, participatory design cannot continue to be a standardized public process. Designing with participation in mind must become contextual, inclusive, immersive, substantive, and comprehensive. Democratic methods for use in participatory design, in addition to great intentions, need to be improved. Innovative methods can improve the connections between communities and creators. Democratic design is transactive; it promotes a process of giving and taking between community members, designers, experts in the field, and influential people.(PeΓ±a 2017)

Every community has professionals who are experts in the political, social, cultural, and physical environments they inhabit. According to the current conditions of economic organization, the most powerful interests receive the most visibility and the most profits due to the Internet protocol's inherent openness. Moreover, the Internet is a medium that portrays both the positive and negative aspects of society. The broad powers of the Internet have the power to both free and exclude members of the community. Urban government is now the subject of several Internet-related projects, experiments, and initiatives at the municipal level, with the goal of using the capabilities of contemporary technology to increase the degree of information and engagement of citizens in urban concerns. Development professionals' perspectives on development have changed because of the transformational nature of modern technology. They promote ICTs as a brand-new paradigm for democratization, economic growth, and international advancement. (Fernandez-Maldonado and Ana Maria 2005)

Because they may access government information and services online and participate more actively in the administration and control of public processes, residents who live in favoured regions in terms of welfare and democracy will benefit from the growth of the Internet. The great irony is that the Internet has the potential to improve people's access to services and participation, which will lead to greater standards of living, in those nations with the lowest levels of democracy and welfare. That is only a reflection of the enormous social separation between wealthy and developing countries, which is another manifestation of what is known as the "digital divide" at the global level. (Fernandez-Maldonado and Ana Maria 2005)

Therefore, examining the spatial effects of cyberspace on cities is crucial for urban studies, which have overlooked the problems due to telecommunications (Graham and Marvin, 1996).(Fernandez-Maldonado and Ana Maria 2005)

5.1.1 Virtual Cities in Developing Countries: The Case of Lima

But what happens in areas that are not part of global capital networks, tourism, or the public interest? Are virtual cities applicable in underdeveloped areas and cities? It is precisely in such circumstances that virtual cities may be able to influence democratization and participation. This is due to lower levels of internet connection in developing countries and, consequently, lower levels of content development and internet services compared to developed countries. However, with the widespread use of the Internet, "virtual cities" are increasingly appearing in developing countries.(Fernandez-Maldonado and Ana Maria 2005)

It has been helpful to recognize new and diverse trends and efforts for people's information and engagement in urban problems that have been growing with and without the aid of modern technology by looking at the phenomena of virtual cities in Lima. The barriadas, which make up most Lima's neighbourhoods, are where these experiences are more obvious.

The citizens of Lima's surrounding suburbs have a history of being quite organized, particularly involved in dealing with local urban concerns, and actively seeking information and political participation at the local level. (Fernandez-Maldonado and Ana Maria 2005)

This need for more participation in decision-making, management, and the urban development of local communities is partially being met through the process of implementing virtual cities in Metropolitan Lima. Particularly in the case of towns in impoverished and remote areas, which obviously lack sufficient financial and technological resources, this process is still in its initial stages. (Fernandez-Maldonado and Ana Maria 2005)

However, this does not imply that the Internet, virtual cities, or ICTs are automatically "democratizing" instruments. Virtual cities, though, are straightforward and affordable tools that could help make local governments more open, receptive, and participatory for the benefit of the entire population in deprived areas with a high dynamic of grassroots organizations and bottom-up initiatives, as in the barriadas settlements in Lima.(Fernandez-Maldonado and Ana Maria 2005)

5.2 Participatory in virtual environment

The question is, can VR systems engage citizens in this decision-making process and promote a bottom-up approach for defending plurality inside cities rather than top-down interventions?

VR systems may enable increased participation and improved decision-making in the planning process by focusing the emphasis on urban areas observed at the street level utilizing a variety of viewpoints as opposed to the view from above. As we will see some cities, non-profit planning groups, and businesses are employing virtual reality as part of a plan to solicit public opinion on planning-related issues, while others are using it to promote new properties to prospective purchasers. (Whyte and Nikoli 2018)

Participatory planning emphasizes including the entire community in the strategic and management processes of urban and rural planning; resolving disagreements; and coordinating viewpoints across numerous distinct groups of stakeholders. By creating settings that people can enter and interact with directly, VR improves the quality of input received from these groups and enables the visualization, communication, and evaluation of new advancements. The idea is that participatory planning emphasizes the group, with decision-and policymaking taking place through continual active contact amongst all stakeholders, rather than merely during a one-time "consultation" exercise, as is now the case. It focuses less on "problem fixing" and more on collaborative learning, empowerment, and continuing partnerships and participation, which means that everyone shares responsibility for creating a new urban environment that will benefit all. (Gowling WLG 2019)

5.2.1 Case studies (Palimpsest)

VR constructs, which are related to participatory planning, can also play a more intimate part in the design of future cities and developments. Palimpsest, a project at University College London, aims to investigate how new projects can harm communities and offer a sympathetic way to experience such an impact. Our initiative captures individual tales and local history using 3D scanning and virtual reality, layering them over the city at a 1:1 scale ("Palimpsest | Interactive Architecture Lab") In locations undergoing significant urban renovation, creating this shared memory is particularly crucial.

The UK High-Speed Rail 2 project is used as a case study in our second effort, The Camden Palimpsest. It explores how people's lives will change by highlighting the tales of Camden residents, some of whom will lose their homes and places of employment. By employing innovative technology to directly connect communities, governments, and developers in discourse, our virtual palimpsests seek to establish more inclusive planning procedures.

The feedback mechanism used in conventional urban planning is theoretically redesigned in this case study of HS2.

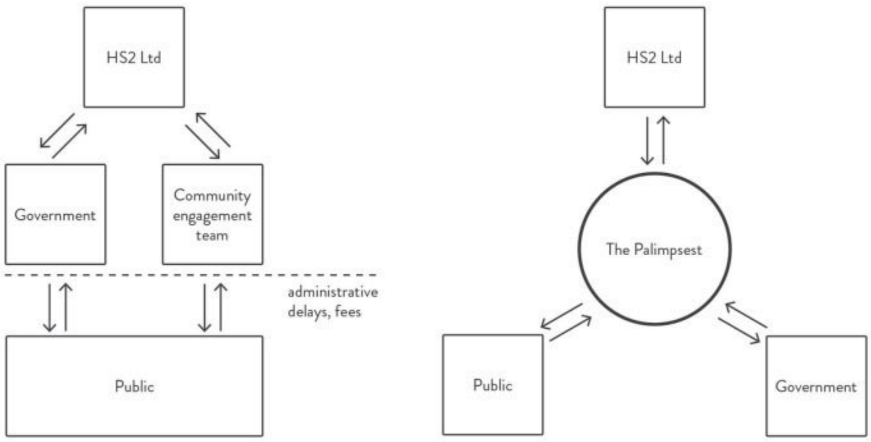


Figure 5.1 The case study of HS2 presentation (Gowling WLG 2019)

This is an amazing example of potential applications for virtual reality in the future. We could witness a moment when VR technology is utilized by protestors to effectively illustrate to others the potential harm that communities may experience, rather than only by developers to showcase their gleaming new structures. (Gowling WLG 2019)

Our solution to enhance participatory urbanization is The Palimpsest. Virtual reality and 3D scanning are both used in the project for different tasks. The first is enabling local communities to record 3D images of themselves, their surroundings, and any significant architectural features to preserve them. During discussions on the project, it also serves as a platform for their narratives. Second, The Palimpsest serves as an impartial forum for all stakeholders engaged in the project—from communities to governmental agencies to businesses—to present their ideas and engage in discussion. In this way, citizens may give comments while viewing government plans 1:1 in virtual reality. (Beaumont 2016)

5.3 Public Participation and e-Democracy

In two completely diverse ways, virtual cities first attracted attention in the middle of the 1980s. The first was the notion that cities might be equipped to let residents engage in a range of domestic activities, namely shopping and other forms of entertainment. Economic growth based on high-tech networks, which would give cities a new competitive edge using high tech for various forms of economic linkage, was parallel to this. The development of computer mapping and computer graphics, which started in the 1960s using remote media such as line printers, vector plotters, and primitive display tubes, led to the second type of usage: professional. (Hudson-Smith, Evans, and Batty 2005)

From initiatives to increase community awareness to the official, quasi-legal involvement in the decision-making process, the spectrum of participatory styles and techniques that entail including individuals in policy and planning concerns are extensive. Since the publishing of the Skeffington Report, there has been a statutory right to appeal against planning decisions in the United Kingdom, and formal participation has been a necessity for local government plan production ever since (MHLG, 1969). (Hudson-Smith, Evans, and Batty 2005)

Although categorizing this spectrum of participation is impossible, Arnstein (1969) provided a helpful and well-established model whose "ladder" maps participatory processes onto "8 rungs." These rungs range from non-participation at the bottom of the ladder, which trend the public by the plan, planner, or politician, to tokenism in the middle, which reflects the one-way traffic of providing information under the guise of consultation, to various levels of direct citizen power and control at the top. The citizen's involvement in in creating a plan increases as one climbs the ladder. The typical methods of face-to-face interaction and hard copy dissemination, which were the primary means of dissemination when Arnstein (1969) drafted her paper, are obviously different from engaging the public through computers and networks. (Hudson-Smith, Evans, and Batty 2005)

The core of the modern e-government approach is the concept of online service delivery. The e-democracy initiative, which is a part of this, aims to increase levels of participation by citizens in the democratic process at a local and regional level by utilizing innovative technologies that heavily rely on ideas of the virtual city and the disseminating of information over the internet. Technologies are viewed as crucial to promoting democratic participation and fostering a sense of engaged citizenship. The focus is on whether modern technology may help involve segments of the community who, for social, economic, or cultural reasons, do not participate in conventional modes of public consultation and what role it might play in bringing policymakers and regular citizens together. (Hudson-Smith, Evans, and Batty 2005)

To have a more democratic planning process, it is crucial to be realistic about the information delivery capabilities of technology. The content of the virtual city can get muddled due to the potential discrepancy between how the government must broadcast planning issues and what the public is interested in. Instead of offering a comprehensive set of tools that the public can use to create their designs, such virtuality is mostly a visualization of surroundings acting as a forum for further discussion and engagement. (Hudson-Smith, Evans, and Batty 2005)

The obvious toolbox of concepts and techniques that could help such a democracy become ingrained in electronic media is offered by virtual cities. Even if online voting systems are the most visible example of e-democracy, the content of potential ballots is more important than the technicalities of how they can be recorded. There is not a plan to create this kind of evaluation system for planning proposals in this situation. (Hudson-Smith, Evans, and Batty 2005)

5.4 A ladder of citizen participation

The contentious debate over "citizen participation," "citizen control," and "maximum practical involvement of the poor" has been fought using exaggerated language and deceptive euphemisms. Three government social programs—urban renewal, anti-poverty initiatives, and Model Cities—are used as examples to present a typology of public engagement to promote a more informed discussion. Each step of the ladder-like typology's intentionally provocative arrangement corresponds to the degree of the public's influence on the plan or program. (Arnstein 2007)

The essential question is: What is citizen engagement, and how does it relate to the contemporary social imperatives?

Because of the political controversy surrounding the topic, the main solutions have been carefully hidden behind words like "self-help" or "citizen involvement." Others have been supplemented with deceptive languages, such as "total control," which nobody — not even the president of the United States — has or can have. (Arnstein 2007)

The ability to influence the process's outcome is fundamentally different from simply going through the traditional motions of involvement. A poster created by French students this spring to explain the student-worker uprising effectively captures this distinction. In Figure 1, the main concept that participation without a reorganization of power is a pointless and discouraging exercise for the weak is highlighted in the poster. It makes it possible for only certain of those sides to benefit while allowing the holders of power to claim that all sides were considered.(Arnstein 2007)

FIGURE 1 *French Student Poster. In English, I participate; you participate; he participates; we participate; you participate . . . They profit.*

Figure 5.2 French student poster (Arnstein 2007)

Analysis of this complex subject might be improved by a typology of eight levels of engagement. For illustrational reasons, the eight kinds are organized in a ladder-like arrangement, with each step representing the degree of citizen control over the result. (Figure 2) Manipulation and therapy are the two rungs at the bottom of the ladder. These two rungs represent different degrees of "non-participation" that have been created by some people to act as a stand-in for actual engagement. Their true goal is to allow those in positions of power to "teach" or "cure" the participants, not to allow individuals to participate in developing or implementing programs. (Arnstein 2007)

Rungs 3 and 4 advances to "tokenism" levels that permit hearing and speaking: Three) Informing; four) consulting Citizens can hear and be heard when they are presented by those in positions of authority with the full range of involvement. However, given these circumstances, they are powerless to guarantee that the influential will pay attention to their opinions. When the involvement is limited to these levels, there is no follow-through and no "muscle," thus there is no guarantee that the status quo will change. Because it allows for advice but preserves the power holders' continued authority to make decisions, rung 5 Placement is just higher-level tokenism. (Arnstein 2007)

Levels of citizen authority with increasing levels of decision-making are found higher up the ladder. Citizens can bargain and make trade-offs with traditional power brokers by entering a (6) Partnership. The highest levels, (7) Delegated Power and (8) Citizen Control, provide have-not people most seats at the table or total management authority. Although the eight-rung ladder is simplified, it helps to highlight the fact that there are substantial gradations in citizen participation, which many people have overlooked. Understanding these gradations enables one to break through the hyperbole and comprehend the power elite's range of confusing answers as well as the have-nots' more vociferous participation demands. (Arnstein 2007)

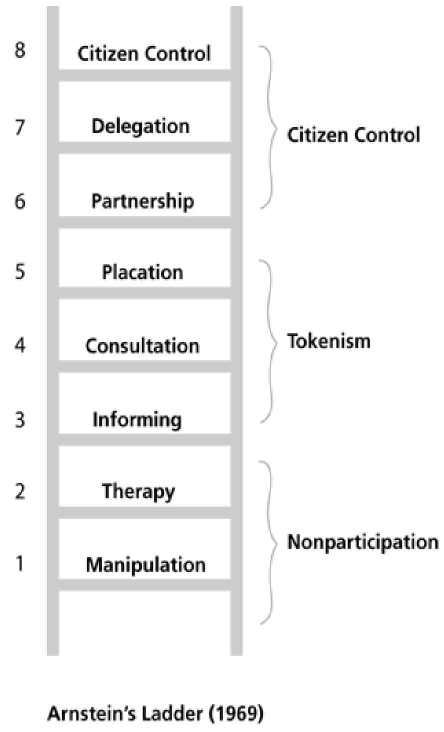


Figure 5.3 Arnstein's Ladder of Citizen Participation (Arnstein 2007)

5.5 Designing democratic community networks

Local interests rather than abstract concepts of the public good, which link-local acts to regional and national agendas, may be the driving force behind community planning, which may resemble normative state procedures a little. What is planning like and what does it mean for communities?

Communities frequently self-select. People who connect, whether via real-world interactions or online networks, tend to identify as group or community. They do this because they have something in common, such as living nearby (or working nearby, depending on the situation), or having a common interest that encourages frequent interaction. (Finney 2017)

5.5.1 Case studies

For example, a charitable organization Reporters Without Borders has created a virtual library in the video game Minecraft to provide censored books and articles to users. The virtual library, dubbed The Uncensored Library, contains articles that have been prohibited in nations such as Egypt, Mexico, and Russia. To avoid governments from spying on the virtual library's contents, the team chose to install it inside Minecraft and use blockchain cloud storage. (Finney 2017)

Heierli explained, "The library can be downloaded as an offline map." "After that, the offline map is saved on a decentralized blockchain cloud storage system that can't be hacked."

"Each map can be downloaded and uploaded multiple times, allowing the library to grow," he concluded. "There are currently over 200,000 copies, making it hard to close the library, even for Reporters Without Borders." By collecting, sharing, and authoring their own books in the game, users can "playfully interact" with the library's contents. The Uncensored Library allows players to read books, but they cannot edit the content of the books on the server.

The virtual world was built by twenty-four people from sixteen nations using 12.5 million "digital Lego blocks." "The library's design is based on old Roman and Greek architectural traditions," Heierli explained. "In the construction of public buildings around the world, such as museums, galleries, and libraries, the neoclassical architectural style is frequently utilized to represent culture and knowledge." (“The Uncensored Library gives gamers "a haven for press ... - Dezeen”) (Finney 2017)

5.6 The Prosumer Movement

Presumption involves both production and consumption rather than focusing on either one (production) or the other (consumption). (“Production, Consumption, Prosumption: The nature of capitalism in the ...") The presumption is said to have been a feature of previous forms of capitalism (producer and consumer capitalism). We have reason to believe that assumption will become more important given the recent growth of user-generated information online. Prosumer capitalism differs from previous kinds of capitalism in how control and exploitation are carried out. Unpaid labour is becoming more popular, as is the practice of providing goods for free. The system is also characterized by a new abundance where scarcity once reigned. These developments point to the potential for pro-consumer capitalism. (Ritzer and Jurgenson 2010)

The developed (and a substantial portion of the less-developed) world's economies have been controlled by capitalism for the previous few centuries. Production, particularly in the factory, dominated its early years. Much more recently, the emphasis has switched to consumption, with the mall challenging, if not completely replacing, the factory as the economic hub. However, we contend that consumption has always predominated in the capitalist economy (and even in pre-and non-capitalist economies) (Ritzer, 2009). Instead of concentrating on either one (production) or the other, prosumption incorporates both output and consumption (consumption). (Ritzer and Jurgenson 2010)

Although prosumption has always been dominant, recent social changes, particularly those related to the internet and web 2.0 (also known as the user-generated web, such as Facebook, YouTube, and Twitter), have made it even more prominent. More specifically, prosumer capitalism is characterized by a new abundance where scarcity once reigned, a tendency toward unpaid labour rather than paid labour, and the offering of goods at no cost. Control and exploitation take on a distinctive character in prosumer capitalism than in other forms of capitalism. (Ritzer and Jurgenson 2010)

The economy of the West, if not western culture, was defined by production from the start of the Industrial Revolution until two centuries later. During that period, the emphasis on output was always there while discussing the economy.

Although the word "producer" may not have always been used to describe the "core" of society, it is unquestionably what most observers had in mind. The clearest illustration of this kind of thinking is, of course, to be found in the writings of Karl Marx who, despite understanding consumption and production are inextricably linked (and vice versa), firmly felt that production held a dominant position in the capitalism of his time. (Ritzer and Jurgenson 2010)

The development of what could be a new form of capitalism is what we observe with digital prosumption online. The four main points in this article highlight its specificity: capitalists find it harder to control prosumers than producers or consumers, and prosumers are more likely to resist; exploitation of prosumers is less pronounced; a unique economic system may be developing there where services are free and prosumers are not paid for their work; and there is abundance rather than scarcity, a focus on effectiveness. (Ritzer and Jurgenson 2010)

5.7 Control, Surveillance and Privacy

Control of the communication environment stands at the basis of communication technology's conflicting public/private character. We observe the growth of privacy as a social value at the turn of the century, along with a movement in life from the uncontrollable external to the controllable inner. The more we want safety, the more we disregard the security that human interaction provides. Risk and chance-taking are linked to denial of commitment. Because of potential dangers, we shun others and rely on technology to decrease risk. Technology, on the other hand, may provide a sensation of control, however illusory it may be. (Ishida 2000)

Safety comes in second place behind physiological demands and ahead of the desires for love, esteem, and self-actualization. So, according to Maslow, once basic demands for self-preservation are met, the desire for a sense of security and the avoidance of physical harm, disease, and violence takes precedence. There is an ardent desire to live in a safe, predictable environment, as well as a desire to avoid places and situations that are viewed as potentially harmful or out of control.(Ishida 2000)

Simultaneously, as online activity increases, each mouse click leaves a data trail that tracks transactions and interactions. Monitoring is increasingly associated with informational surveillance and online contact, rather than just visual or auditory observation of public activity and interaction. Privacy regulations may result in the formation of digital cities that are unable to trade with one another. (Ishida 2000)

The city is potentially a place of social interaction and auditory/visual stimulation is composed of architectural elements (commercial buildings, homes, construction, etc.), urban environmental factors (streets, stores, restaurants, cafes, advertising, etc.), transportation settings (public and private), and people. The social life of the digital city is composed of nodes, servers, links, websites, chat rooms, MUDs, etc., providing diverse options and encounters. Both the physical and digital surroundings should, in theory, contain a mix of order and disorder, of predictability and unpredictability.(Ishida 2000)

The social environment of physical and digital cities is shaped by regulatory infrastructure, which consists of a system of rules, codes, laws, and legal precedents that all influence social interaction.(Ishida 2000)

In recent decades, established methods of representative democracy have come into question, with observers from all over the world expressing 'alienation' and 'disconnection' from traditional political processes. This is because societies have transformed: they have become more diversified, more complicated, and less willing or able to comply to the class orthodoxies

(Misztal, 1996; see also Revelli, 2006) that supported a simple left-right politics. (Nick Gallent and Daniela Ciaffi 2014)

Indeed, traditional divisions have blurred, and new communities have emerged across a variety of physical and virtual networks, each with its own set of social and political goals. Since the 1970s, urban and non-urban social movements have gained traction (Mathieu, 2010). (Nick Gallent and Daniela Ciaffi 2014)

Communities just mobilize in many cases and in reaction to numerous stimuli. Their faith in the government to solve issues or seize opportunities has gone, or people recognize the virtue and wisdom in doing things for themselves. Local measures done by community groups, as well as the projects they provide themselves, are often tremendously successful. As a result of this accomplishment, governments that have spent years trying to resurrect parliamentary democracy – or just discover more effective procedures for delivering local services – see a chance to reclaim their own legitimacy. They join with community activity wherever it occurs, fostering and claiming it as their own. They try to force it to happen where it does not occur naturally.(Nick Gallent and Daniela Ciaffi 2014)

Academics, political activists, community members, and a variety of other voices have criticized established top-down government and well over control, and a growing disenchantment with past political orthodoxies has resulted in a broadening enthusiasm for direct community engagement in policy design and planning, which has lasted beyond local elections. (Nick Gallent and Daniela Ciaffi 2014)

It may be easier to 'unfriend' those who hold opposing viewpoints in the virtual world or to rapidly quit one group and join another. Different interests and viewpoints must, however, coexist in the same socio-spatial community in the real world. We can point to cracks or the existence of sub-groups or cliques, but the lived fact is that communities rarely speak with one voice, and conflict is an inevitable component of the make-up of dynamic social organizations based on social exchange networks. (Nick Gallent and Daniela Ciaffi 2014)

With the emergence of the internet, new perspectives on the nature of community have emerged. Those who deny the importance of place communities frequently do so considering the prevalence of virtual lives, in which people discover deeper connections and a clearer sense of purpose online than they do offline.(Nick Gallent and Daniela Ciaffi 2014)

Reflections on growing internet connectivity have aided thinking about the concept of place-community. This interconnection has highlighted the importance of social interaction and network dynamics in the formation of a community. (Nick Gallent and Daniela Ciaffi 2014)

5.8 Dark side of Virtual cities on social interaction

The growing use of monitoring and feedback mechanisms in sophisticated systems, as well as the hazards this poses to privacy and autonomy, is a major concern. Information about behaviour is required to improve communication, navigation, and awareness in digital cities: log files, cameras, tracking, profiling, and user feedback systems.

Technologists like this type of information because it allows them to monitor and improve their systems; business owners want it because it allows them to make money; politicians use it for control and surveillance; and sociologists love it because it is a rich data source for analysing use and user behaviour, as well as the implications of technical systems on social processes. (Ishida 2000)

Another concern is the conflict between digital cities' commercial and social ambitions. Investment in digital infrastructure and services necessitates resource-rich customers. Despite the social intentions such initiatives may have at first, this may deepen the digital gap. Private enterprises, on the other hand, should be part of the collaboration if the purpose of social networks and digital cities is to improve opportunities and access to resources for low-income groups (jobs, subsidies, etc.). However, without being able to take control of the entire idea to commercialize it. (Ishida 2000)

5.9 Conclusion

This chapter introduced that virtual reality systems can offer features and applications, such as the capacity for social interaction, and be useful for participating in and designing democratic societies. For example, they enable increased participation and improved decision-making in the planning process by focusing the emphasis on urban areas observed at the street level utilizing a variety of viewpoints as opposed to the view from above.

In addition, the right of citizens to participate in political decisions that affect their daily lives is considered a matter of democracy. To be democratic, participatory design cannot continue to be a standardized public process. Designing with participation in mind must become contextual, inclusive, immersive, substantive, and comprehensive. Democratic methods for use in participatory design, in addition to great intentions, need to be improved. Innovative developments such as big data, VR/AR systems, and digital cities can improve the connections between communities and creators. Moreover, these developments are a medium that portrays both the positive and negative aspects of society.

Furthermore, by creating settings that people can enter in the participatory process and interact with directly, VR improves the quality of input received from these groups and enables the visualization, communication, and evaluation of new advancements. The idea is that participatory planning emphasizes the group, with decision-and policymaking taking place through continual active contact amongst all stakeholders, rather than merely during a one-time "consultation" exercise, as is now the case. It focuses less on "problem fixing" and more on collaborative learning, empowerment, and continuing partnerships and participation, which means that everyone shares responsibility for creating a new urban environment that will benefit all.

By analysing some case studies like Palimpsest, we can consider the solution to enhance participatory urbanization as the potential answer for virtual reality in the future.

Accordingly, the core of the modern e-government approach is the concept of online service delivery. The e-democracy initiative, which is a part of this, aims to increase levels of participation by citizens in the democratic process at a local and regional level by utilizing innovative technologies that heavily rely on ideas of the virtual city and the disseminating of information over the internet. Although categorizing this spectrum of participation is impossible, Arnstein (1969) provided a helpful and well-established model whose "ladder" maps participatory processes onto "8 rungs." The citizen's involvement in creating a plan increases as one climbs the ladder.

In conclusion, virtual cities are like all systems, and in addition to their advantages, they also have their negative impacts and dark sides, which should be considered. For instance, concerns about privacy and autonomy are raised by the expanding usage of monitoring and feedback mechanisms in complex systems. Also, according to safety the concept of privacy and control is discussed. The more we want security, the more we ignore the security that human interaction provides. Privacy regulations may result in the formation of digital cities that are unable to trade with one another.

Another concern is the conflict between digital cities' commercial and social ambitions. Investment in digital infrastructure and services necessitates resource-rich customers. Despite the social intentions such initiatives may have at first, this may deepen the digital gap.

Chapter 6: Conclusion

This chapter outlines the main contributions of this thesis in six subcategories.

6.1 Evaluation the current situation

This thesis presented the development of virtual reality and relatable applications in design, simulation, and construction in urban planning. **Many cities throughout the world are constructing or considering developing virtual city models with various aspects and goals.** Professional architects simulate digital twin cities based on real-time data collected from pre-**installed IoT sensors and machine learning to analyse potential urban planning options in a smart city.** For example, VR constructs, which are related to **participatory planning**, like Palimpsest, can also play a more intimate part in the design of future cities and developments. Also, the term can refer to systems that employ the city paradigm, such **as virtual communities for collaboration and participation.** By creating settings where people can enter the participatory process and interact**, they directly improve the quality of input and enable the visualization, communication, and evaluation of new advancements. Participatory design is direct democracy in action and allows the building of a democratic city.** Moreover, humanity's relationship with the idea of democracy can be reflected in the physical **surroundings where democratic discourse takes place.**

Due to this, **we expect to see more changes and improvements with the use of VR and AR technology in redesigning future cities with less risk and with a better result for having a democratic city.**

6.2 Answer to thesis questions

- ***What are the impacts of virtual cities on urban planning?***

As was previously mentioned, digital interaction tools have become more complex and widespread. The ability to record, process, manipulate, and display information about the built environment has increased because of our rising usage of digital information and our ability to access that information across virtual cities. The operation, management, and repair of urban planning have become more reliant on digital data. As a result, virtual cities give us the option to evaluate all the aspects of urban planning before applying. These simulations can be developed to estimate future urban planning choices in a smart city. For example, with additional data available, simulations could be made that were more accurate and included current data on local traffic, noise pollution, and crowding. We can also simulate the answering model in emergencies.

- ***How has the urban planning been operated, designed, and developed using virtual reality?***

Virtual reality is becoming an increasingly popular planning tool. The visualization of planning and design materials provides crucial planning support for the creation of landscape architecture. Virtual reality models facilitate communication and help people grasp planning proposals by enabling citizens to appreciate the spatial and temporal processes of design. Testing the VR models in three-dimensional (3D) spatial design revealed that 2D models and aerial images are also required to facilitate orientation on-site, and the best outcomes are obtained by combining these tools. Projects involving public participation in the analysis and evaluation of urban development models are examples of potential uses for virtual urban simulation. Residents can take a detailed look at the projects to grasp the concept and express their comments thanks to interactive technologies. More information about the region and its residents is included in the virtual urban simulation (VUS) system when it is used in conjunction with GIS. This information includes land plot data, the availability of government grants for redevelopment, and resident characteristics, such as residents' willingness to take part in the process. The user may easily and comfortably access all forms of necessary information by highlighting it or otherwise identifying it thanks to the integration of VUS and GIS. However, it is unlikely that having access to the data layers in real-time can automatically produce information regarding a specific land parcel's eligibility for redevelopment.

- ***How will the implementation and bridge between real and virtual cities look?***

The study shows that the physical city may be used to design digital cities, which either connect the real and virtual worlds or build virtual cities for digital populations. But the significance of the symbiotic relationship between physical and digital cities should not be lost in the infatuation with technology and the problems that the digital city presents. However, because the nature of space in the virtual world differs fundamentally from that of the real world, the virtual world's architecture requires theory and methodology. For this reason, the virtual world was chosen as a platform for study and experimentation with the aim of (re) establishing the function of founding architecture using the principles of functional organization in the virtual world.

- ***How do virtual cities help citizens participate in decision-making to have a democratic city?***

VR systems may enable increased participation and improved decision-making in the planning process by focusing the emphasis on urban areas observed at the street level utilizing a variety of viewpoints as opposed to the view from above. The right of citizens to participate in political decisions that have an impact on their daily lives is referred to as the democratic imperative. Participatory design is direct democracy in action. It is based on the typical locations and lives of people. To be democratic, participatory design cannot continue to be a standardized public process.

Designing with participation in mind must become contextual, inclusive, immersive, substantive, and comprehensive. Democratic methods for use in participatory design, in addition to great intentions, need to be improved. Innovative methods can improve the connections between communities and creators. Democratic design is transactive; it promotes a process of giving and taking between community members, designers, experts in the field, and influential people. Technologies are viewed as crucial to promoting democratic participation and fostering a sense of engaged citizenship.

The focus is on whether modern technology may help involve segments of the community who, for social, economic, or cultural reasons, do not participate in conventional modes of public consultation and what role it might play in bringing policymakers and regular citizens together. But to have a more democratic planning process, it is crucial to be realistic about the information delivery capabilities of technology.

6.3 Advantages/ Disadvantages

Advantages of virtual cities:

- Enhancing citizen engagement
- Building trust between government and citizens
- Access to public policy services
- Involving in decision making
- Developing innovative solutions (emergencies, traffic, green space, …)
- Examining public reviews of the proposed facilities
- Monitoring the progress
- Less risky choices

Disadvantages of virtual cities:

- Hard to simulate exactly like physical model
- Life span of model
- Need professional modelers and architects
- Rapid changes in technology
- Monitoring, controlling and privacy subversion
- Security concerns
- Gap between the different user generations

6.4 Implementation

Based on the evaluated outcomes of the study, the thesis successfully answers the questions regarding technology and design, forming a new definition of architecture for the digital age. **A virtual city, besides all its positive and negative effects, is a tool to make urban planning decisions clear for citizens and non-professionals.** Building information modelling (BIM) and computer-aided design (CAD) tools have long been used by architects, engineers, construction companies, and city planners to assist them in designing, planning, and building their projects.

However, with the advent of the **internet of things (IoT) sensors**, **big data, and cloud computing,** they can now produce **"digital twins"** of entire cities and model how things will seem and function in a variety of circumstances.

Analysing the various techniques of public participation reveals that each one has advantages and disadvantages, but also that each one engages a particular sector of the community and evaluates the plan from a particular viewpoint. This leads us to the crucial conclusion that diverse approaches to public participation should be combined in complex situations to provide the greatest results possible. To prevent repetition, the best approaches must be chosen while considering the project's and the community's cultural, ethical, technical, social, and other elements.

To conclude, as we have previously mentioned**, by considering the impacts of this technology, we should use it as a positive solution for urban planning and have a democratic participation tool.**

6.5 Future perspective

The thesis tried to point future designers and thinkers toward a new set of considerations. With the improvement of virtual reality technologies and their applications, we also have a lot of options. **Digital technologies, for instance, might improve our understanding of the interactions between the built and natural environments, giving us a wider perspective of the physical world.** Alternatively, t**he built environment itself might become more cyber-physical, further isolating us from our physical surroundings.** Additionally, we should expect a rise in the convergence of VR and associated technologies that use sensors, BIM, big data, artificial intelligence, and VR in new ways. We might also give these technologies' carbon footprints more consideration. We may look forward to technological advancements such as:

- More integration of VR with BIM
- More wearable and auto-stereoscopic devices
- More data capture and video
- More sensory-rich applications
- New platforms that support a range of uses and applications
- Distributed virtual environments, and teleoperations

6.6 Critical comments

Based on the conclusion we came to in this thesis, there are still certain limitations and critical opinions on the subject. As mentioned before, for modelling the city, there are still limitations **to having the exact model as the real one.** However, with the improvement of technology, we need to constantly update the model, which creates an economic and budget problem for this type of project, **and we will have a short life span for each model.**

Moreover, by having virtual cities, what happens in areas that are not part of global capital networks, tourism, or the public interest? Are virtual cities applicable in underdeveloped areas and cities? It is precisely in such circumstances that virtual cities may be able to influence democratization and participation. For example, developing countries have a problem with a lower level of internet connection compared to developed countries, which need an improvement in virtual technologies as the basic technology for the internet, which makes the processing for democratizing society longer.

Another important question is, can VR systems engage citizens in this decision-making process and promote a bottom-up approach to defending plurality inside cities rather than top-down interventions? VR systems may enable increased participation and improved decision-making in the planning process by focusing the emphasis on urban areas, However, this does not imply that the Internet, virtual cities, or ICTs are automatically "democratizing" instruments. Also, virtual cities as a tool for democratization help society with transparency between governments and actions and help citizens share their ideas and opinions regarding the decisions.

Which puts the system of virtual cities in the middle of the leader of citizen participation, tokenism, which reflects the one-way traffic of providing information under the guise of consultation, to various levels of direct citizen power and control at the top.

Regarding the challenges related to this system, we can see the potential of all the positive points that this system in the future can provide, not just for users but also for urban planners, but we should always take care of the negative parts to have a better result in the end. we should be careful of the privacy of users, the budget, and the life span and see how we can be sure that instead of this helps us for democratizing the cities instead of giving the tool to governments for controlling.

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