Faculty of Engineering

Department of Architecture and Built Environment

Resilient Design for London's Elevated Social Spaces: Exploring Challenges, Opportunities, and Harnessing Interactive Virtual Reality Co-design Approaches for Community Engagement

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"The most beautiful thing we can experience is the mysterious.

It is the source of all true art and science."

Einstein, 1949

Abstract

In the face of escalating urban density, the emerging concept of elevated urban spaces such as sky gardens and roof gardens is becoming a compelling requirement for human well-being in the process of densification. These spaces have gained additional significance in light of the adaptability and resilience required during the Covid-19 pandemic. This research explores the challenges and opportunities related to the design and management of such spaces, with a specific focus on London. A novel facet of this investigation is the application of Virtual Reality (VR) technology as a co-design tool, aimed at enhancing public engagement and the overall design experience of these spaces. The study emphasizes two particular urban locales in London: the Sky Garden and Crossrail Place, chosen for their unique design characteristics, public accessibility, and popularity. These case studies allow for an in-depth examination of critical design aspects such as accessibility, people flow control, pinch points, user experience, and the spectrum of activities that these spaces can accommodate.

To create more sustainable and inclusive environments, the study leverages VR technology to bridge the gap between the physical and virtual worlds. This approach is aimed at understanding the impact of this integration on architectural and urban design processes, specifically in terms of design decision-making and its implications for the sustainability and longevity of public places. The adopted methodology is a phenomenological qualitative approach employing the Participatory Action Research (PAR) method. This involved direct observational studies, walk-along interviews with 33 visitors at each site, VR exploratory experiments with the same number of participants, and follow-up semi-structured interviews. Observations were conducted before, during, and after the Covid-19 pandemic, providing a comprehensive perspective on the unique challenges influencing the design and management of elevated urban spaces.

The results indicate that VR, as a co-design tool, effectively promotes interactive public participation in the design process. The VR experiments facilitated users to identify design limitations and suggest improvements, even among participants who had not physically visited the sites. The concerns and needs identified through VR closely mirrored those expressed by actual users of the spaces. The findings also offer a comparative analysis of human activities, circulation patterns, and design considerations in both physical and virtual environments, highlighting the potential of VR technology for designing sustainable public spaces in a post-pandemic world.

This research contributes threefold: (a) it furnishes theoretical input by establishing guidelines for the design of elevated social spaces, and provides empirical input by suggesting a range of design and planning considerations for developing active, pleasant, and resilient elevated social spaces; (b) it offers methodological input through the development of a multidisciplinary pragmatic framework for assessing the use of VR as an interactive co-design tool; and (c) it presents a comparative analysis of two advanced interactive VR approaches – Building Information Modeling (BIM) and gamification techniques – to enhance public engagement in public and social space design.

Keywords: Virtual Reality; Computational design; Gamification; Participatory design; Elevated Public Spaces; Covid-19.

Publications

Journal Articles

Ehab, A., Burnett, G., & Heath, T. (2023). Enhancing Public Engagement in Architectural Design: A Comparative Analysis of Advanced Virtual Reality Approaches in Building Information Modeling and Gamification Techniques. Buildings, 13(5), 1262. https://doi.org/10.3390/buildings13051262

Ehab, A., & Heath, T. (2023). Exploring Immersive Co-Design: Comparing Human Interaction in Real and Virtual Elevated Urban Spaces in London. Sustainability, 15(12), 9184. https://doi.org/10.3390/su15129184

Book Chapters

Ehab, A., Heath, T., & Burnett, G. (2023). Virtual reality and the interactive design of elevated public spaces: Cognitive experience vs VR experience. In C. Stephanidis, M. Antona, S. Ntoa & G. Salvendy (Eds.), HCI International 2023 Posters. HCII 2023. Communications in Computer and Information Science (Vol. 1836). Springer. https://doi.org/10.1007/978-3-031-36004-6_24

Bussell, C., Ehab, A., Hartle-Ryan, D., & Kapsalis, T. (2023). Generative AI for immersive experiences: Integrating text-to-image models in VR-mediated co-design workflows. In C. Stephanidis, M. Antona, S. Ntoa & G. Salvendy (Eds.), HCI International 2023 Posters. HCII 2023. Communications in Computer and Information Science (Vol. 1836). Springer. https://doi.org/10.1007/978-3-031-36004-6_52

Ehab, A., & Heath, T. (in press). Rethinking the design of vertical green spaces in the post-pandemic era: Visitor behaviour and real-life cognitive experience at Crossrail Place, London. In Resilience vs. Pandemics: Innovations in Public Places and Buildings (Book II in the Urban Sustainability Book Series). Springer.

Ehab, A., & Heath, T. (in press). Critical Factors Affecting the Design and Use of Elevated Urban Spaces: The Sky Garden, London. In Climate Change and Environmental Sustainability (Advances in Science, Technology & Innovation). Springer, Cham.

Conference paper

Ehab, A & Heath, T. (2021). Rethinking Sustainable Vertical Urbanism: The Death and Life of Vertical Social Spaces. EMDOC Conference 2021, Leicester, UK Retrieved from https://emdocblog.wordpress.com/portfolio/1418/

Personal Narrative

Growing up in the heart of Cairo, a city steeped in rich history and marked by an intense population density, my fascination with urban planning and architecture began to blossom. Cairo, suffering from a notable lack of green spaces due to its substantial density of 19,376 individuals per square kilometre and thus positioned as the 37th most populated city worldwide and the second in Africa, kindled my initial interest in vertical urbanisation. The city's vibrant, historic streets and its inspiring architecture, particularly the ancient Egyptian pyramids regarded as the world's first vertical cascading tall structures, further fuelled my curiosity about the concept of sustainable vertical urbanism.

My curiosity transformed into a definitive career path during my tenure at the British University of Egypt, where I studied sustainable urban design. Here, I grappled with the compelling dichotomy between burgeoning urban density and the indispensable human necessity for open, green spaces. This exploration deepened during my master's degree at the University of Nottingham, as I investigated sustainable tall buildings and vertical urbanism.

After my master's degree, I gained professional experience working in academia and industry, which further enriched my understanding of urban design. In recognition of my commitment and dedication, the University of Nottingham awarded me the Faculty of Engineering Research Excellence PhD Scholarship in 2019. This scholarship enabled me to delve deeper into my PhD research, aiming to enrich the dialogue on the sustainable use of urban spaces. Specifically, I focused on elevated spaces and their potential for enhancing urban resilience, particularly in crisis situations exemplified by the Covid-19 pandemic. I was intrigued by the potential application of novel technologies like Virtual Reality (VR) in the design process and its role in facilitating public participation. This led me to closely study unique elevated urban spaces, such as London's Sky Garden and Crossrail Place.

During my PhD, I immersed myself in the comprehensive examination of these spaces, scrutinising their design, human interaction, and the diversity of activities they facilitated. I discovered that factors like accessibility, flow control, pinch points, and user experience were critical in shaping their public use and acceptance. Concurrently, I investigated VR's potential as a co-design tool through a series of experiments and interviews. These endeavours yielded invaluable insights into the technology's effectiveness for public engagement, providing a robust longitudinal perspective on the dynamics of these spaces during different pandemic phases.

My understanding of sustainable urban design was concurrently honed through practical experiences as a Lecturer Assistant in Egypt, Studio Tutor at the University of Nottingham, and Research Assistant on the Derby Urban Sustainable Transition (DUST) project. My collaboration with diverse stakeholders on the DUST project, including creating interactive VR city models and designing two new roof gardens, reaffirmed my conviction in the untapped potential of elevated urban spaces.

In conclusion, the outcomes of my research substantiated VR's potential in urban design and augmented my understanding of elevated urban spaces. I intend to leverage these insights in creating sustainable, resilient, and inclusive urban spaces and democratising design decisions using advanced interactive VR technologies. Reflecting on my journey, my PhD has been an expedition of growth, exploration, and overcoming challenges. My endeavour to bridge physical and virtual worlds in the realm of urban design has unravelled new possibilities for the development of public spaces. With a steadfast commitment to sustainability, inclusivity, and resilience, I am eager to contribute to urban design's future in a post-pandemic world.

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This thesis would not have reached completion without the invaluable contributions from numerous individuals throughout the various stages of research. First and foremost, I am deeply grateful to my primary supervisor, Prof. Tim Heath, for his unwavering support, guidance, encouragement, and faith in my abilities. His significant impact on my research and academic growth has been immense, and I truly owe him a great deal for his dedication to my success. I would also like to extend my appreciation to my secondary supervisor, Prof. Gary Burnett, for his insightful advice, constructive critiques, and expertise in the technical aspects of the VR methodology. Additionally, I am thankful to Dr. Florian Wiedmann for his contributions as my third supervisor. I am particularly grateful to my internal examiner, Dr. Amy Tang, for her critical and inspiring input, which significantly enhanced the quality of this thesis.

I am indebted to the University of Nottingham and the Faculty of Engineering for awarding me the Faculty of Engineering Research Excellence Scholarship, which enabled me to pursue this PhD course. I also wish to express my gratitude to the Human Factors Research Group, the Department of Architecture and Built Environment, and the Graduate School for fostering a nurturing academic environment that enriched my scholarly journey.

My thanks go to the Derby Urban Sustainable Transition (DUST) Group at the University of Derby for the opportunity to work as a Research Assistant in Architectural Technology during the final two years of my PhD, which expanded my knowledge and expertise in designing urban spaces, roof gardens in VR, and writing papers. I am grateful to my line manager and Project Head, Prof. Chris Bussell, for his ongoing support, as well as my colleagues Timo Kapsalis and Daniel Hartle Ryan.

During the period of my PhD research, I was fortunate to be able to tutor in the Urban Design studio and Vertical Community studio classes. The countless discussions and innovative ideas I encountered with students undoubtedly contributed to my research journey. I would also like to express my appreciation to all organisations and individuals who offered assistance and support towards the completion of this study. My sincerest gratitude goes to all key informants and research participants for their time, knowledge, and cooperation during interviews, field experiments, and site discussions.

I dedicate heartfelt thanks to my parents, Ehab Salah and Hanan, and my brother, Omar, for their endless love, inspiration, and strength throughout this process. I am also grateful to my friends in Nottingham and Egypt for their unwavering support. This intellectual, mental, and emotional endeavour has been the most challenging yet rewarding journey I have undertaken, and I am fortunate to have encountered such incredible individuals along the way. To all who have contributed to this journey, thank you.

Contents

List of Figures

List of Tables

Glossary

The subsequent table elucidates the definitions of various terms frequently employed in this thesis and commonly found in the related field of study. It is of utmost importance for a comprehensive understanding of the research. While this glossary is not exhaustive, it aims to furnish the reader with the most pertinent information and explanations of terms used in the thesis.

Term	Acronym	Definition	Source
Public Space	-	Physical space with a free and open circulation of people at all times, accessible to all citizens regardless of ethnicity, gender, age, and socioeconomic status. Also defined as a representation of sociability and democracy against the rapid growth of commercialisation and globalisation.	Carmona, 2010, 2021; Shaftoe, 2008; Keane, 2018; Mitrasinovic,2006; Juris, 2016; Watson 2006; Young, 1990
Public Realm	-	Understood as streets, alleys between buildings, squares, bollards: everything that can be open to public access and considered part of the social and physical built environment.	Gehl & Svarre, 2013
Territory	-	Deeply ingrained concept, not only for human families, tribes, and society, but in most of the natural world, representing space that can safely be shared, or must be private.	Potts, & Lewis, 2014; Elton, 2012
Agora	-	Public space in ancient Greece, similar to a trading market, where the public came to trade, hear proclamations, meet, and vote. Symbolic representation of the joint concepts of citizenship, law, and democracy.	Crawford, 2021; Sennett, 1998; Dickenson, 2016; Madanipour,1999
Third Places	-	Casual gathering places, privately-managed and owned spaces that have become essential locations for select public activities such as informal gatherings, people watching, and accidental encounters.	Oldenburg, 1991, 2002

Publicness	**-**	Publicness is the extent to which a space is accessible and the regulatory parameters that govern this accessibility. It involves an inquiry into the entities that control the space, the rules they enforce concerning its use, and their decision-making process to determine who may or may not use it. It encapsulates the dynamic interplay between space and its socio-political context, challenging notions of public-private dichotomies, power structures, and democratic access to space.	De Magalhaes & Trigo, 2017; Low & Iveson, 2016; Minton, 2006, Brill, 1989
Private Public Space	-	Spaces that are open to the public but under private ownership and control. They include spaces in private shopping centers, rail and bus stations, and inside public buildings like libraries, churches, or town halls.	Carmona, 2019
Skycourts	-	Elevated open spaces within tall buildings that provide semi-public spaces for the occupants of the building.	Pomeroy, 2013
Skygardens	-	Elevated landscaped areas that provide semi-public spaces for the occupants of the building or the general public.	Pomeroy, 2013
Elevated Parks	-	Parks that are constructed above ground level, typically on structures built specifically for them or on existing structures such as rooftops or disused railways.	Pomeroy, 2012
London Garden Squares	**-**	These are public and private squares with gardens, enclosed by buildings on all sides, which first appeared in London in the 17th century.	(Goodman, 2003; Carmona & Wunderlich, 2013)
Compact City Model	-	An urban model which promotes high density, mixed use and public transportation as a more sustainable and beneficial form of urban development.	Oldfield, 2019

Hyper-Densities		Urban densities exceeding 350 units per hectare, often achieved through the construction of tall buildings**.**	Oldfield, 2019
Densification		Process of increasing density without increasing sprawl of an urban settlement: filling in brownfield sites, installing transport connectivity, raising building height.	Oldfield, 2019
Urbanisation (vs Population growth)		Process of population moving from low density living (agriculture, rural) to city areas.	Oldfield, 2019
Hybrid Urban Spaces	-	Areas that, despite not being publicly owned or governed, are increasingly used as communal locations. They display unique typologies, attributes, and regulatory systems compared to traditional public spaces.	Cho et al., 2015; Carmona, 2019; Ali & Al-Kodmany, 2012; Holl, 2014
Hybridisation	-	A process involving heightened interaction between structural and programmatic components in urban spaces. It aims to minimize transportation needs and augment the local environment by incorporating green spaces.	Lehmann, 2016; Churchman, 1999; Pomeroy, 2013
Spatial Hybridisation	-	The process of creating complex structural arrangements and technological advancements that interact with the surrounding context to generate new spatial conditions conducive to enhanced access, connectivity, physical flexibility and innovative public uses.	Frantzeskaki et al., 2017; Cho et al., 2015
Programmatic Hybrids	-	The combination of various activities that are mutually complementary and conducive to unconventional uses of space.	Cho et al., 2015, 2017; Iveson, 2013
Operational Hybrid Framework	-	A recently developed framework for spatial negotiation, aiming to transform access, territoriality, and conventional boundaries by incorporating negotiated ownership, safety optimization,	Cho et al., 2017; Lehmann, 2016

		space utilization, management, and scheduling.	
Hybrid Buildings	-	Buildings characterized by a high degree of programmatic complexity and encompass both the architecture and the urban context. They integrate shared common spaces and highly connected areas to create a cohesive building that operates as a unified whole. Regular building functions (e.g. hotel, retail, housing, office) may co-exist with leisure, subways and transport.	Pomeroy, 2013; Oldfield, 2019; Al-Kodmany, 2018; Cho et al., 2015
Elevated Green Social Spaces	-	A type of public spaces that are distinguished by their elevation above the surrounding ground plane, and private ownership and management.	Hadi et al., 2018; Pomeroy, 2013; Osmundson, 1999
Bioclimatic Skyscrapers	-	Tall buildings designed to be in harmony with the environment, by harnessing natural light, air, rainfall, solar energy, recycling, and green nature, reducing total energy balance equation to zero.	Yeang, 2002; Yeang & Richards, 2007; Yeang, 2008
Virtual Building (also BIM, see below	-	A concept that facilitates the generation of construction plans, sections, and elevations from a 3D model.	Bazjanac, 2006
Architectural Engineering and Construction	AEC	A sector that utilizes virtual building concept for conveying architectural notions.	Eastman et al., 2011
Building Information Modelling	BIM	A process supported by various tools, technologies and contracts involving the generation and management of digital representations of physical and functional characteristics of places.	Eastman et al., 2011
Internet of Things	IoT	Network of physical devices embedded with sensors, software, and other technologies for the purpose of connecting and	Chettri & Bera, 2019; Chui et al., 2010

		exchanging data with other devices and systems over the Internet	
Computational Graphic Imagery	CGI	The application of the field of computer graphics (or more specifically, 3D computer graphics) to special effects	Eastman et al., 2011
Virtual Reality	VR	A computer-generated simulation of an environment or situation that places the user inside an experience, it can be similar to or completely different from the real world	Sutherland, 1965; Eastman et al., 2011
Augmented Reality	AR	An interactive experience of the real-world environment where the objects that reside in the real world are enhanced by computer-generated perceptual information	Azuma, 1997
Mixed Reality	MR	A hybrid of real and virtual worlds where digital and physical objects coexist and interact in real-time	Milgram & Kishino, 1994
Extended Reality	XR	A term that includes all its immersive technologies, the ones we currently have and the ones that are still to be created. This includes everything from Augmented Reality (AR) to Virtual Reality (VR) and Mixed Reality (MR)	Lindgren & Johnson-Glenberg, 2013
Immersive Virtual Environments	ImVE	A virtual environment that provides a high level of immersion, such as VR, AR, and MR	Wolf et al., 2020
Immersive Virtual Reality	ImVR	An advanced form of VR that aims to provide users with a higher level of immersion by integrating additional sensory stimuli and creating a more seamless and convincing experience. It often employs advanced tracking technologies, haptic feedback systems, and more sophisticated graphics and sound, fostering a stronger sense of presence in the virtual environment.	Safikhani et al., 2022; Zhang et al., 2021; Rubio-Tamayo et al., 2017; Meenar & Kitson, 2020; Sanchez-Sepulveda et al., 2019; Yu et al., 2022; Kim et al., 2020; Panya et al.,2023
Sensorama	-	A prototype for an immersive, multi-sensory (hearing, vision, smell, and touch) theater experience	Heilig, 1962; Pope, 2018

Presence	-	The sensation of being in a virtual or physical environment. It is influenced by technological immersion and affected by user-tracking, stereoscopic visuals, and broader visual display fields of view.	Slater & Wilbur, 1997; Conroy, 2001; Kalawsky, 2000; North & North, 2016; Cummings & Bailenson, 2016
Virtual Collaborative Design Environments	-	Virtual spaces developed to improve communication, collaboration, understanding, and knowledge sharing among participants. These environments often employ communication tools like text-based tools, voice chat tools, visual sharing tools, and avatars.	Roupé et al.,2020; Safikhani et al., 2022; Wen & Gheisari, 2020; Monahan et al., 2008
Avatar Movement	-	The movement of an avatar (a virtual representation of a user) in a virtual environment. Research has discovered that avatar movement is effective in conveying non-verbal information, thereby enhancing collaboration efficiency.	Wen & Gheisari, 2020; Monahan et al., 2008
Gamification in Architecture and Urban Design	-	Incorporating game design elements and principles into non-game contexts, such as architectural planning, urban development, and design visualization.	Deterding et al., 2011; Münster et al., 2017
Unreal Engine	UE	A game engine developed by Epic Games, known for its high-quality graphics and powerful real-time rendering capabilities.	Fonseca et al., 2017; Kharvari & Kaiser, 2022
Blueprints system		A coding system in Unreal Engine allowing architects and urban planners to develop customized interactions in the virtual environment.	Kavouras et al., 2023; Calvo et al., 2018

Chapter 1- Research Introduction

1.1 Introduction

This research scrutinizes the challenges and factors impacting the design and management of elevated social spaces in London, including roof gardens, sky gardens, and elevated parks. The study further investigates the potential of immersive VR technology as an interactive tool for co-designing these spaces, with an aim to enhance their resilience. The trend of developing these spaces has emerged in response to the escalating demand for green and social spaces in increasingly dense urban areas. While elevated social spaces offer a distinctive urban experience and serve as a respite from the city's fast pace, their design necessitates considerations of circulation, management, publicness, accessibility, activities, biophilic integration, and social resilience. The unexpected global phenomenon of Covid-19, in the midpoint of the study, brought in a whole new dimension to the study, emphasising the importance of deeply considered precautions for public health in the design and management of elevated urban spaces. Covid-19 stimulated the study to expand into the use of VR for experiencing public spaces.

The Covid-19 pandemic has presented new challenges for managing these spaces, such as ensuring social distancing and adequate ventilation. The deployment of Extended Reality (XR), particularly Virtual Reality (VR), in architecture and urban design introduces both benefits and challenges, including high costs, compatibility issues, and public acceptance. The design of elevated social spaces is a complex process involving multiple stakeholders who could potentially benefit from the use of VR to facilitate a more authentic co-design approach and framework, thereby involving the public in a significant manner.

Chapter one comprises four distinct sections, each serving a specific purpose in laying the foundation for the study. The first section, "Research Context, Problem Definition, and Motivations", provides a comprehensive overview of the research context, a clear definition of the problem, and an examination of the issues that motivated the study. This section establishes the backdrop against which the research is being conducted and lays the groundwork for the subsequent sections.

The second section, "Scope of the Study, Research Aims, Objectives, and Questions", delineates the study's boundaries and outlines the research aims, objectives, and questions that will guide the investigation. This section is crucial in establishing the study's overall direction and focus, and it provides the basis for the research design outlined in the following section.

The third section, "Research Approach", presents a comprehensive overview of the overall research approach adopted for the study. This section includes an explanation of the research design, data collection and analysis methods, and the criteria for evaluating the results. The research approach guides the investigation and ensures that the research aims and objectives are systematically and rigorously achieved.

The final section, "Thesis Structure", provides a summary of the main content of the subsequent chapters and serves as an overview of the thesis's overall organization. This section offers a roadmap for the reader, enabling them to anticipate the flow of information and understand the interrelationship between the study's different components.

In conclusion, this chapter serves as the study's foundation, offering a clear and comprehensive overview of the research context, scope, aims, objectives, and methodology. It provides a crucial starting point for the reader and sets the stage for the subsequent chapters, which delve into the investigation's specific details (Figure 1.1.).

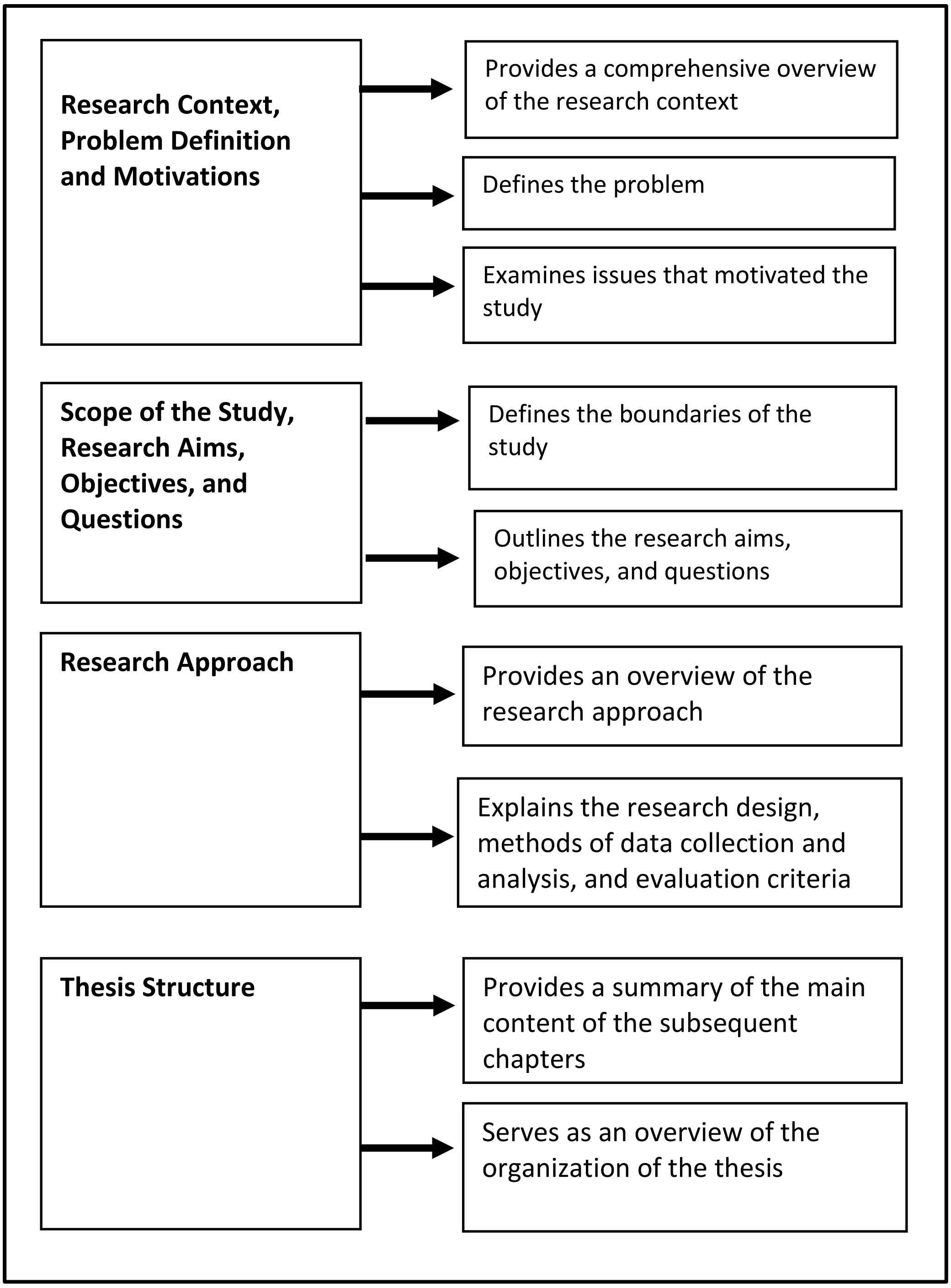


Figure 1.1: Diagram illustrating the primary sections covered in Chapter 1. Source: Author.

1.2 Research Context & Problem Definition

The Greater London conurbation and the City of London is a vibrant and dynamic urban region that is undergoing significant growth and transformation (Mell & Whitten, 2021; Hagan, 2019). As a response to the growing demand for green and social spaces, a trend of creating elevated social spaces has emerged in the form of roof gardens, sky gardens, and elevated parks. These spaces offer a distinctive and elevated view of the city, as well as providing a means for residents and visitors to escape the frenetic pace of urban life (Pomeroy, 2013; Tian & Jim, 2011; Jones, 2017).

The City of London and Canary Wharf stand as unique urban entities within the Greater London landscape. These areas are not just financial powerhouses but also represent the epitome of modern urban development, characterized by their iconic skyscrapers, bustling streets, and a blend of historical and contemporary architecture. Unlike typical residential areas, these districts are dominated by commercial and business activities, drawing in a diverse population of professionals, tourists, and city dwellers on a daily basis. The sheer density and vibrancy of these areas present both challenges and opportunities for urban planners and designers. The creation of elevated social spaces in such contexts is not merely an aesthetic or recreational endeavor but also a strategic response to the pressing need for more public spaces amidst the concrete jungle.

In contrast to residential neighborhoods, where elevated social spaces might serve as extensions of private living areas or communal gathering spots, in the City of London and Canary Wharf, these spaces take on a multifaceted role. They cater to the needs of a transient population, offering respite during work breaks, facilitating informal business meetings, or simply providing a vantage point to appreciate the city's skyline. The design and functionality of these spaces must, therefore, be approached differently. They must be versatile, catering to a broader audience, and be resilient to the dynamic nature of these urban hubs. The juxtaposition of these elevated spaces against the backdrop of towering skyscrapers and historic landmarks offers a unique urban experience, distinct from the more homely and intimate feel of elevated spaces in residential areas.

The development of pedestrian-oriented activity above the ground plane has opened up a novel dimension of urban space within cities, the concept of a permeable continuum in the city environment (Cho et al., 2015; Pomeroy,2012). This has encouraged the creation of additional points of interest, thereby revitalizing buildings, from being closed-off and glazed tubes of commerce to being, in part, recreational spaces of the city (Al-Kodmany, 2018; Al-Kodmany et al., 2022). The reconceptualisation of public spaces into a more three-dimensional framework can offer increased opportunities, and can potentially create a safer environment for individuals within urban areas (Mualam et al., 2019; Viñoly et al., 2015). The inclusion of ample outdoor social spaces within mixed-use developments can thus play a significant role in the creation of thriving and sustainable communities. These spaces give extra value to the mental map of inhabitants, in a sense, giving them a shared 'front-garden' beyond their own small balcony or doorstep (Hadi et al., 2018; Samant & Hsi-En, 2017).

The concept of vertical social spaces can be characterized by their spatial morphology and ability to mitigate the perceived density of tall buildings or high-density developments (Oldfield, 2019; Cho, 2022). This is achieved through the fragmentation of mass and erasing the monotony of repetitive floor plates and sheer glass walls. The ground plane is extended, penetrating the closed façades, moving under, through and upwards into city buildings to form a new experience of space in the city. These spaces can evoke a sense of human scale and proportion by appearing within high-density urban habitats, thereby striking a balance between the form of the building and its surroundings (Ali et al.,2012; Al-Kodmany, 2011; Hadi et al., 2014).

The new phenomenon of elevated social spaces has increased noticeably in London in recent years. These spaces offer a unique and multi-functional environment for social interaction, recreation, and relaxation. Elevated social spaces do need not to be hard paved, functional sky-courts. They can play a crucial role in providing much-needed green spaces in densely populated urban areas, serving as a welcome respite from the fast-paced city life, and offering a distinctive alternative to traditional public spaces (Pomeroy, 2013; Li et al., 2022). The green planted content of the spaces can meet the unspoken but essential biophilic need for the well-being of the human soul – contact with nature (Raji et al, 2015).

The design qualities of elevated social spaces are essential in ensuring that these spaces are multipurpose, aesthetically pleasing, and conducive to well-being. These spaces must be designed to be accessible, safe, and secure, with clear circulation routes and well-designed areas for different activities (Lehmann, 2016; Cho et al., 2015).

However, despite their growing popularity, there remains a gap in the research surrounding the challenges and factors facing the design of elevated social spaces in London. This includes issues such as circulation, management, publicness, accessibility, activities, green content, social resilience, and mitigating the impact of the Covid-19 pandemic (Samant, 2019; Viñoly et al., 2015). Understanding these challenges and factors is crucial in ensuring the successful design and management of elevated social spaces that are accessible, inclusive, and sustainable for all users (Oldfield, 2019; Taib et al, 2010; Yuen, 2005). Therefore, a deeper examination of these challenges and factors is necessary to inform the design and management of elevated social spaces in London and to enhance the overall quality of these spaces for the community.

The time of Covid-19 and the period of the post-pandemic have brought about a rapid change in the way the world functions, with far-reaching impacts, felt in various sectors, including the urban environment (Afrin et al., 2021; Shroff, 2020). Elevated social spaces, such as the Sky Garden in the City of London, and Crossrail Place in London's Canary Wharf have been especially affected, due to their reliance on large crowd attendance and high foot traffic. These spaces serve as vibrant public areas that provide ample opportunities for social interaction and cultural exchange, making them vital components of the urban fabric. The pandemic has created new challenges for the management of these spaces, particularly in terms of ensuring social distancing and adequate ventilation (March & Lehrer, 2022; Bereitschaft & Scheller, 2020). There are also issues around accessibility, particularly for people with disabilities or mobility difficulties, which must be taken into consideration in the design of these spaces. Additionally, the publicness of these spaces must be carefully considered, with clear guidelines and policies in place to ensure that these spaces are accessible and welcoming to all members of the community (Cho et al., 2015).

The use of Extended Reality (XR) in architecture and urban design has the potential to provide several benefits. XR technologies can help architects and urban designers to simulate and test different design scenarios and make data-driven decisions about the design of public and social spaces (Stals & Caldas, 2022; Alizadehsalehi,2020). XR technologies encompass a wide range of digital experiences, ranging from virtual to augmented reality (Abhari et al.,2021). In particular, Virtual Reality (VR) has gained significant attention as a tool for architects and urban designers (Jamei et al., 2017). In addition, interactive VR experiences offer designers and planners a unique opportunity to test and refine their designs in a virtual environment. VR can test environments that may never result in a physical building, and can save the viewer from having to travel (Portman et al., 2015). By incorporating VR into the design process, designers can create a realistic representation of the proposed space, allowing them to assess the feasibility of different design options and make informed decisions (Zaker & Coloma, 2018).

VR enables designers to visualise the finished space, making it easier to communicate their vision to stakeholders and the wider community. VR also provides a valuable opportunity for designers to engage with the community and gather feedback on their designs. By creating interactive VR experiences, designers can invite the public to explore and provide feedback on the proposed space, making the design process more inclusive and accessible. This type of engagement allows designers to gather valuable insights into what the community would like to see in the finished space and make changes accordingly (Sanchez-Sepulveda et al., 2019; Schrom-Feiertag et al., 2020).

However, the use of VR in architecture and urban design also presents a number of challenges (Kalantari & Neo, 2020). One of the main challenges is the high cost of VR hardware and software, which can make it difficult for designers to access these technologies (Cook et al., 2019; Khan et al., 2021). There are also issues around the technology itself, including compatibility and interoperability issues between different VR systems and software. In addition, the procedures and processes involved in using VR in architecture and urban design can be time-consuming and complex, requiring a significant investment of resources and expertise (Safikhani et al., 2022). Finally, getting the public engaged in a safe environment due to the high possibility of motion sickness effects and the physical space requirements (Saredakis et al., 2020).

The design of elevated social spaces is a complex and multi-disciplinary process that requires the integration of multiple stakeholders, including designers, urban planners, policymakers, and, most importantly, the public. In recent years, the use of interactive virtual reality (VR) experience has emerged as a promising tool for creating a participatory design approach that needs to be further investigated. This technology offers new opportunities for designers and the public to collaborate and test their ideas in a virtual environment, allowing for the exploration and evaluation of different design options and strategies in real-time (Sanchez-Sepulveda et al., 2019; Hsu et al., 2020).

1.3 Research Scope

The research scope for this thesis will focus on the challenges and factors facing the design and management of elevated social spaces in London, with a particular emphasis on the use of interactive virtual reality (VR) experiences. The research will focus on the following fields/areas:

1. Circulation: Examining the challenges and factors that affect cognitive and physical accessibility and the circulation of people in and around elevated social spaces.

2. Management: Investigating the policies and procedures that impact the management of these spaces, including safety, security, and maintenance.

3. Publicness: Exploring the publicness of elevated social spaces, including their public accessibility and inclusion for all members of the community.

4. Activities: Analysing the types of activities that can be carried out in these spaces, as well as the potential for collaboration between designers and the public.

5. Social resilience: Examining the potential for elevated social spaces to promote social resilience and foster a sense of community in urban areas.

6. Biophilia and mental health: Providing the restorative and healthy benefits of contact with green nature for urban citizens, especially those in the high-density city without a suburban garden of their own.

7. Impact of the Covid-19 pandemic: Evaluating the impact of the Covid-19 pandemic on the design and management of elevated social spaces.

8. Use of VR in architecture and urban design: Investigating the potential benefits and challenges of using VR to design elevated social spaces, allowing for community engagement in the design process.

The study is conducted using a qualitative research approach, utilizing interviews, surveys, VR experiments and observations to gather data. The research focused on relevant literature in the fields of architecture, urban design, computational design and public policy.

1.4 Research Aim & Objectives

The study seeks to explore the challenges facing London's vertical or elevated social spaces in terms of accessibility, controlling people flow, pinch points, user experience, and activities. The research aims to analyse the performance of the new suggested solutions for creating vertical social spaces that feel safe, operate effectively, and add value for users and developers. Furthermore, this study aims to test the effectiveness of VR for evaluating elevated social spaces, compared with the real experiences of citizens, through the examination of existing literature and the implementation of case studies and surveys.

The main objective of this study is to investigate the future potential of VR technology as a co-design approach for designing such spaces in London. Reflecting on this, then, to develop a comprehensive framework for the design of London's vertical public realm in enabling community engagement and participation in the design of elevated social spaces.

Table 1.1 Research Questions & Objectives (Source: Author)

No.	Research Questions	Objectives
1	How do various challenges and factors impact the design of elevated social spaces in London?	To identify the design qualities of elevated social spaces by developing a comprehensive understanding through the analysis and synthesis of various approaches and cases studies To provide a guideline for the adaptability and the social resilience of vertical urban spaces.
2	How has Covid-19 pandemic impacted upon the design and management of elevated social spaces in London?	To observe and study visitors' behaviour, circulation and activities before, during and post-pandemic.
3	What are the benefits and challenges of using VR in architecture and urban design for	To validate and test a proposed model portraying the influence of an interactive VR experience for the design of public and social spaces.

	the design of elevated social spaces in London?	To investigate the users' behavioural response toward VR in an immersive environment
4	How can VR technology be utilised to gather feedback from the community and stakeholders on the proposed design of elevated social spaces?	To develop a framework for the design of elevated social spaces in London that considers VR technologies and community engagement.

1.6 Research Approach

In order to achieve the aim and objectives of this study, the initial step involved scoping the relevant topic areas that would inform the research project. Three crucial areas were then investigated: the historical background and design challenges of private-public spaces in London; the design attributes and constraints in utilising elevated social spaces during the post-Covid era; and the utilisation of Extended Reality (XR) technology, with a specific emphasis on interactive Virtual Reality (VR) experiences in urban design.

The literature review revealed a significant gap in knowledge regarding the impact of Virtual Reality (VR) on decision-making and participatory design in public and social spaces. Additionally, there is a need to investigate the effect of visualisation and mode of interaction on user experience in the virtual world in comparison to the real environment. The advancements in traditional desktop applications over the years have led to improved user experiences and expectations. Thus, the transition from traditional desktop applications to immersive VR requires consistent application design guidelines. Consistency in these guidelines is imperative, given the reports from professionals regarding their experiences in the VR environment. The present study aimed to explore how interactive VR experiences facilitated by Head Mounted Displays can impact the use, behaviour, circulation, and activities of individuals in the design of elevated social spaces.

Therefore, it was a prime task to adopt a phenomenological qualitative methodology to examine the suitability of the theories employed in the context of this study and, more importantly, to identify context-specific variables and incorporate these within a conceptual framework for further testing through subsequent data collection. The proposed qualitative model was subsequently validated through quantitative measures to reinforce its validity and the generalizability of the results. Through this approach, a final VR interactive participatory design model was developed, which represents the primary contribution of this study. The theoretical contributions and practical implications, specifically in regard to the design of elevated social spaces using immersive interactive VR experiences, were emphasized as a research framework towards a co-design approach in the concluding chapter of the thesis.

In conclusion, the research approach of this study focused on the design of elevated social spaces in the post-Covid era and investigated the use of Extended Reality (XR) technology, with a specific emphasis on interactive Virtual Reality (VR) experiences. The literature review revealed a gap in knowledge regarding the impact of VR on decision-making and participatory design of public spaces. An exploratory qualitative methodology was adopted to validate a proposed VR interactive participatory design model, which represents the primary contribution of this study. The study emphasizes the theoretical contributions and practical implications of using immersive interactive VR experiences in the design of elevated social spaces, towards a co-design approach. The findings of this study can inform future design practices and contribute to the advancement of VR technology in elevated social spaces design.

1.5 Thesis Structure

The thesis structure is organised into two major sections, each dedicated to a specific aspect of the research study. The first part includes a comprehensive literature review, while the second part is dedicated to the primary data collection, and analysis of results. To provide a clear and concise overview for the reader, the thesis comprises of nine chapters in total. The following is a brief synopsis of each chapter, highlighting the key objectives and findings of the research.

Chapter 2 (Research Background): The History of Private-Public Spaces in London

In Chapter 2, the concept of public space, social space, and vertical social space is thoroughly discussed and defined. The chapter also offers an insightful look into the historical evolution of private public spaces in London. To better understand the current state of public spaces in the city, the chapter presents an analysis of the eight principles of the London Charter for public spaces, which serves as a guiding framework for their delivery and management in new urban developments. Furthermore, the chapter explores the impact of London's anticipated urbanisation on its public spaces and highlights the growing need for the creation of three-dimensional elevated urban spaces to address the spatial and territorial challenges of urbanisation.

Chapter 3 (Literature Review): Hybrid Urban Spaces and Elevated Social Spaces in London

Chapter 3 of this thesis explored the literature review of elevated social space design in London, with a particular focus on the post-Covid and future pandemic context. The chapter delved into the themes of density and hybrid urban spaces, the design history of vertical urban spaces, the linking of biophilia, the freedom to roam, view and breathe, all to support mental health. It looked at the approach taken in Singapore to design vertical green social spaces. It also examined the concept of vertical public realm design and place-making in the sky.

The central aim of chapter 3 was to discuss the design challenges, limitations, and opportunities associated with elevated social spaces in London in a post-Covid and future pandemic context. This included considerations such as accessibility, publicness, activities, circulation, biophilic offer, design, and management in the face of changing social and public health and mental health requirements. The chapter provided a comprehensive overview of the published literature relevant to the proposed research and analysed the design quality of vertical urban spaces and the impact of the Covid-19 pandemic on their design, as well as the potential for future pandemics to shape the design of elevated social spaces.

Chapter 4 (Literature Review): VR in Urban Design- A Study of Tools and Challenges

In Chapter 4, the use of Co-design methods in public space design was thoroughly investigated. This chapter served as an introduction to the innovative XR tools and applications in architecture and urban design, providing a comprehensive overview of immersive XR technologies, with a specific emphasis on VR. This emphasis on VR was motivated by its significance in the present study, as VR represents a key tool for the design process, particularly in exploring human behaviour and interaction with the designed space.

Moreover, chapter 4 delved into the various VR tools, software and applications currently available in the market, exploring the gaps, opportunities and challenges associated with their use in urban design and public space design. The discussion provided an in-depth analysis of the current state of VR in urban design, highlighting the potential of this technology to enhance the design process and improve community engagement. By investigating the use of VR as a design tool, chapter 4 aimed to provide a comprehensive understanding of its role in elevating the quality and impact of public spaces, while addressing the critical aspects of its implementation in the urban design process.

Chapter 5: Research Methodology

The methodology chapter of this research project presents the methods used to collect primary data. Chapter 5 commenced by presenting the philosophical basis of the research, followed by a comprehensive discussion and justification of the research methods. The data collection process for each phase of the research is described in detail, including the design of the instruments, the target population, the sampling method, and the analysis technique. Finally, the chapter discusses the reliability, validity, limitations, and ethical considerations associated with the research design.

Chapter 6 (Results): Cognitive Experience

Chapter6, observed how people are using vertical social spaces before, during and post-pandemic. The study focuses on how vertical urban spaces' design impacts human behaviour and physical and mental health. The research focused on analysing two recent case studies Sky Garden and Crossrail Place Roof Garden. These spaces were selected according to their different typology, location, size, green planting, and rules of management. The study uses direct observation methods, walk-along interviews and space syntax analysis to provide qualitative and quantitative data. This method was chosen to examine critical issues such as accessibility, circulation, activities, limitations of visitors and social distancing.

Chapter 7 (Results): Interactive Virtual Reality (VR) Experience

Chapter Seven presented the qualitative analysis of the Virtual Reality (VR) laboratory experiment carried out. The experiment tested and explored two different methods and tools for creating an interactive design model. One model was based on Building Information Modelling (BIM) software, namely "Autodesk Revit", whilst the other was based on a game engine, specifically "Unreal Engine." The research involved a VR exploratory experiment followed by semi-structured interviews with 33 participants. This method required VR modelling of the existing conditions of two vertical social spaces, the Sky Garden and Crossrail Place roof garden. The study investigated how interactive VR experience and Visual Simulation (VS) technology could enhance the design experience of these social spaces and encourage community engagement. The study aimed to examine individuals' behaviour and interaction within the virtual world.

Chapter 8: Discussion and Conclusion

The final chapter of the thesis amalgamates the insights derived from the study, critically analysing the employed methodologies and comparing these findings with previous studies. The chapter commences by summarising the research outcomes, which unravel in three distinct sections: the development of design guidelines for elevated social spaces, a detailed exploration of the virtual study findings, and discussing the connection between the physical cognitive and virtual studies.

The ensuing section highlights the implications of these findings, focusing on their contributions to both academic knowledge and practical applications in the urban and architectural industry. This chapter also discusses the study's limitations, endorsing a cautious interpretation of the findings. Thereafter, a retrospective examination of the research aims and objectives takes place, emphasising its contributions to existing knowledge and outlining the practical implications for designing elevated social spaces in high-density cities. The chapter concludes by offering recommendations for future research and guidance for design and policy decision-makers, thereby creating a robust foundation for subsequent work in this field.

Thesis Structure

Chapter 2: Research Background	Include a brief description underneath, such as "Defining public space, social space, and vertical social space. History of private-public spaces in London.
Chapter 3: Literature Review - Hybrid Urban Spaces and Elevated Social Spaces	Underneath, briefly outline the key topics, such as "Design challenges, limitations, and opportunities of elevated social spaces. Impact of Covid-19. This chapter defined and highlighted the main research problem.
Chapter 4: Literature Review on VR in Urban Design	• Comprehensive overview of immersive XR technologies, specifically VR • Exploration of VR tools, software and applications in urban design • In-depth analysis of the current state of VR in urban design. This chapter outlined the research gap and objectives.
Chapter 5: Research Methodology	• Explanation of the philosophical basis of the research • Discussion and justification of the research methods • Detailing of the data collection process and analysis technique
Chapter 6: Cognitive Experience	• Observes human behaviour in vertical social spaces during different pandemic stages. • Analyses walk-along interviews and space syntax analysis in case studies of Sky Garden and Crossrail Place Roof Garden.

Chapter 7: Interactive VR Experience

- Analysis of a VR laboratory experiment
- Comparison of models based on BIM software and game engine
- Investigation of individual behaviour and interaction within a virtual world

Chapter 8: Discussion & Conclusion

- Synthesis and evaluation of findings from chapters six and seven
- Presentation of a comprehensive framework and practical guidelines for the resilience design of elevated social spaces
- Retrospective examination of the attainment of the research aim and objectives
- Evaluation of contributions made to the body of knowledge
- Critical analysis of the strengths and limitations of the methods used
- Summary of key findings, recommendations for design and policy decision-makers, and suggestions for further research

Figure 1.2: Diagram illustrating the structure of the thesis, delineating chapters from Literature Reviews through to Data Collection, Analysis, Discussion, and Conclusion. Source: Author.

Chapter 2- Research Background: The History of Private-Public Spaces in London

2.1 Introduction

London is a city with a rich and diverse history, where the evolution of its private and public spaces has been shaped by various factors, including social, economic, and political. Over two centuries of transport and population growth, the city has become a metropolitan conurbation, by combining the city's boroughs into what is now called Greater London. In the recent decades, there has been a significant shift in the way private spaces are used in the city, with a growing trend towards privatisation. This trend has had significant implications for the city's public spaces and has created a new dynamic between private and public spaces in London.

This chapter includes a more focused introduction to the research area and provides the background to the topic investigated (Figure 2.1). The chapter begins by outlining the different definitions of public space, social space, and elevated (also frequently referred to by the author as 'vertical') social space. It also discusses the history of private-public spaces in London. The chapter also reviews the eight principles of the 2022 publication by the London Mayor's office, 'Public London Charter', which aims to provide a basis for the delivery and management of public spaces in new development. Importantly, this chapter examines the challenges of London's future urbanisation; their effects on public spaces and the consequent need for a 3-dimensional understanding of vertical urban spaces.

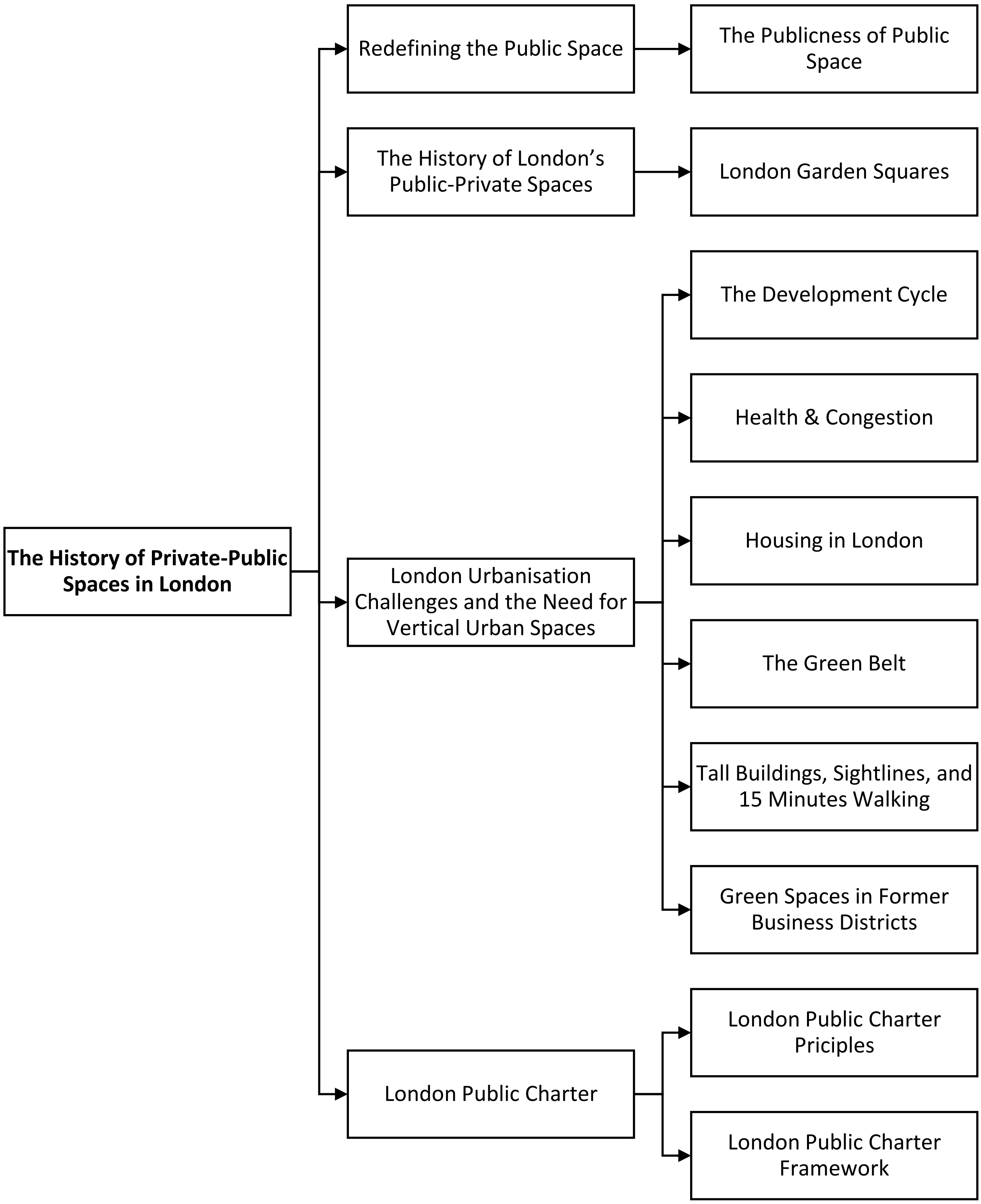


Figure 2.1: Flowchart illustrating the primary sections covered in Chapter 2. Source: Author.

2.2 Redefining the Public Space

The '**public space'** is a challenging term to describe, since the sharing of space, and the phenomenon of legally defining what can be shared space has existed since the beginnings of human society. Wherever there have been settlements or buildings, shared space has had a hierarchical level of access, so that few spaces are or ever were truly or totally 'public' for people (Carmona, 2019; Bohman, 2004; Gehl, 1987). '**Territory'** is deeply ingrained, not only for human families, tribes and society, but in most of the natural world. Almost all examples of animal, aquatic, bird and insect societies have notions of territory, including space that can safely be shared, or must be private; thus the hierarchy of public-private access is integral to existence (Potts & Lewis, 2014; Elton,2012). Even woodland wild plants, fungi and trees are conducting a battle for domination of their territory. Their survival and reproductive cycles depend on an innate understanding and use of territory (Wei et al., 2021; Philo & Wilbert, 2004).

All through history, squares, streets, parks, and street markets were described as the embodiment of public spaces in human society. The remains of Egyptian, Mesopotamian, Central American and Chinese settlements all demonstrate the ritualistic and hierarchical organisation of public space. The Greek Agora was one of the first public spaces in history to be analysed and documented in detail as a social phenomenon (Crawford, 2021). In ancient Greece's first millennium BCE, the Agora was similar to a trading market, but in those times, it was also a place where the public come to trade, hear proclamations, meet and vote (Dickenson, 2016; Madanipour,1999). Documents could be created by scribes; arguments or lawsuits could be heard by elders. Wise men could hold an audience enthralled with philosophical ideas; the thoughts and saying of Plato, Aristotle, and Socrates were faithfully recorded by the scribes.

The Agora was a public space that developed into a symbolic representation of the joint concepts of citizenship, law, and democracy (Crawford, 2021; Sennett, 1998). However, in ancient Greek democracy, citizenship rights were already defined hierarchically, with full citizenship denied to slaves, women and foreigners or exiles (Stone, 2013; Rotroff, 1997). Thus, more than half of this population was excluded from the debate and were not part of this 'public' (Adhya, 2008; Minton, 2006). Examples of the Agora and the Roman equivalent, the Forum, exist (in ruins, or still in use), and the words are still used to brand modern buildings and institutions with a highly respected social concept, that almost needs no explanation (Madanipour, 2019; Bodnar, 2015).

According to Carmona, the typical definition of public space is a physical space with a free and open circulation of people at all times and accessible to all citizens, regardless of ethnicity, gender, age and social-economic status, (Carmona, 2010; Shaftoe, 2012; Carmona, 2021). Public space is also defined as a representation of sociability and democracy against the rapid growth of commercialisation and globalisation (Keane, 2018; Mitrasinovic, 2006), a place for negotiation, protest, debate, and expression of the interests of minorities (Juris, 2016; Watson 2006), with diversity and difference as its significant elements (Young, 1990). Writers and politicians, such as Rosalyn Deutsche, have claimed that public space is the main nodal point where democracy happens. From the political side, they describe public space as a place in which political changes can stake out the territory that enables them to be heard and seen. (Miller, 2007; Deutsche, 1992).

The public space concept does not only include physical space but covers the physical, symbolic, and procedural aspects (Iveson, 2007; Goffman, 2008; Low & Iveson, 2016). Public spaces also refer to all communal and non-communal areas of social life, including all media and recently internet and social media (Humphreys, 2010; Watson, 2006). Madanipour defined public space, if it is to be considered truly ‘public’, as those areas within towns, cities, and the countryside that are physically accessible to everyone, where strangers and citizens can enter with few restrictions (Madanipour, 1999, 2019). Although, the conceptual meaning of open public space was expanded to include 'any place that people use when not at work or home' (Fraser, 2021; Habermas et al., 1974).

According to Campbell, the report by the Scottish Executive Central Research Unit faced a challenge to define **‘Open Space`** and recommended that a common typology was missing from national guidance and legislation (Table 2.1) (Williams & Green, 2001; Campbell, 2001).

Table 2.1. A Typology of Open Space. Source: Kit Campbell Associates (2001)

OPEN SPACE Any unbuilt land within the boundary of a village, town or city which provides, or has the potential to provide, environmental, social and/or economic benefits to communities, whether direct or indirect.	
GREEN SPACE A subset of open space, consisting of any vegetated land or structure, water or geological feature within urban areas.	**CIVIC SPACE** A subset of open space, consisting of urban squares, market places and other paved or hard landscaped areas with a civic function.
Parks and gardens **Amenity greenspace** **Children's play areas** **Sports facilities** **Green corridors** **Natural/semi-natural greenspace** **Other functional greenspace**	**Civic squares** **Market places** **Pedestrian streets** **Promenades and sea fronts**

Source: Kit Campbell Associates (2001)

The permitted level of access is consequently and clearly a key element of the 'publicness' of public space, as is the question of who regulates the space and decides who else is or is not permitted to use it (De Magalhaes & Trigo, 2017). Ownership may be the first determinant, but the assigned management (e.g. bailiff, security, gamekeeper) enforces the regulations. Socially embedded traditions may be the controlling aspect behind how space is used, managed and regulated; collectively, these all combine to play the role of defining the legitimacy of occupying space (Low & Iveson 2016; Minton, 2006, Brill, 1989).

Public life traditionally combined several facets: it was accessible to everyone and welcoming for participation and observation; it was shared by different groups of people and therefore needed tolerance of different behaviours and interests (Mehta, 2014; Brill, 1989; Sennett, 1974). According to Warner, public life requires fairly universal and open social contexts, contrary to private life (Warner & Calhoun, 2003). According to the academic, Peter G Rowe, the success of the public realm lies in its pluralistic nature, allowing much variety of activities or attitudes (Rowe, 2009; Rowe, 1991).

"*Public Realm is understood as streets, alleys between buildings, squares, bollards: everything that can be open to public access and considered part of the social and physical built environment. Public life should also be understood in the broadest sense as 'everything that takes place between buildings'. It is everything we can go out and observe happening – far more than just street theatre and café life*" (Gehl & Svarre, 2013: 2).

2.2.1 The Publicness of Public Space

Recently, most of the public spaces are ruled and controlled by somebody; it could be the local authority (the borough, county, city or ‘Crown’), private individuals, private organisations, or different institutions like the international finance and pension funds associations (Carmona, 2022; Minton, 2006). As an example, the Crown owned most foreshores and beaches in the UK, although parks, with the exception of the Royal Parks, tend to be owned and managed by local authorities, the National Trust or English Heritage (Hubbard, 2020; Goss, 1990). The idea of 'open plan space’ or 'totally free space' is rarely discussed, mainly as a utopian ideal, however, it is rare in practice. Generally, government-owned space is often thought of as 'public,' such as squares, parks and public buildings (Varna & Tiesdell, 2010).

Britain is connected by a system of public footpaths, whose history stretches back to Roman times and probably earlier. However, the right to ‘proceed’ does not give the right to ‘inhabit’, i.e. create an unauthorised settlement. In established settlements, streets are seen by the public as the most ‘public’ of all urban spaces. Large public spaces have long been associated with revolutionary political struggle and exhibitions of state power (Galián, 2019). However, revolutions start in the streets, but as they gather momentum, the participants move to the larger streets, and the action culminates with major events in public spaces (Marom, 2013; Harvey, 2012).

The most famous public spaces have a notable building façade such the National Gallery in Trafalgar Square, to dominate and frame the space. They also have iconic objects or monuments that act as the token presence and gathering site, such as Trafalgar Square’s Nelson’s Column (Sitte, 1889; Cullen, 1961; Lynch 1964). A modern local example is the statue of Brian Clough in Nottingham’s Old Market Square, a favoured meeting point for public demonstrations.

Elevated social spaces such as sky gardens and elevated parks are considered a new form of private public space (Carmona, 2019). Elevated urban spaces not being at street level, must employ a related connecting method, which is to organise a means of arrival (escalators, ramps, elevators); they need pathways through and around the space, with carefully chosen viewing positions for the public to ‘drink in the view’ of specific iconic landmarks such as the nearest skyscraper, the river, the skyline (Cho et al., 2015). These provide an analogous experience to the 'pathways, façade and monument' ideas from Camillo Sitte and Kevin Lynch, and the sequential vision ideas of Gordon Cullen. This is worthy of deeper discussion later in the next chapter.

The various ways of defining 'publicness' are rooted in the changing role and meaning of the public sphere. The redefining of the concept of publicness is identified through the work of Habermas and Arendt. Habermas defines the **public sphere** as the sphere of private people who join together to form a 'public' (Habermas, 2010; Habermas et al., 1974). In the structural change and transformation of the public sphere, a central historical concept is a dynamic and complex relationship between privacy and publicness (Calhoun, 2011).

Both Arendt and Habermas highlight two significant factors to the changing role and meaning of publicness. Firstly, the development and growth of the social realm, along with both the private and the public realms; secondly, the importance to everyday life and activity of what can be done or experienced in the public sphere (Cassegård, 2014; Thompson, 1993). The public realm serves as a central discourse within which several realms of the private and the social forces function (Sennett, 2020; Adhya, 2008).

According to Oldenberg, casual gathering places are also termed 'third places', privately-managed and owned spaces that have become essential locations for select public activities such as informal gatherings, people watching, and accidental encounters (Oldenburg, 1991, 2002). Oldenberg also argues that in the modern era, bars, general stores, shopping malls, and cafes are important to community vitality and local democracy (Oldenburg, 1991, 2013). These opportunities and allowances provided by third places reinforce the value of everyday urban life in the examination of the public realm (Goosen & Cilliers, 2020; Banerjee, 2001). The Munich Putsch of 1923, or the origin of modern banking and insurance in the coffee houses of Halifax and London from 1652, the storming of the Bastille 1789 remind us that great historical events or institutions often start in these 'third places' (Chadios, 2005; Cowan, 2004).

In the modern era, Carmona describes most clearly what we mean by a definition of public space: Public space (broadly defined) "*relates to all those parts of the built and natural environment, public and private, internal and external, urban and rural, where the public has* *free access, although not necessarily unrestricted, access. It encompasses all the streets, squares and other rights of way, whether predominantly in residential, commercial or community/civic uses; the open spaces and parks; the open countryside; the 'public/private' spaces both internal and external where public access is welcomed if controlled – such as private shopping centres or rail and bus stations; and the interiors of crucial public and civic buildings such as libraries, churches, or town halls*" (Carmona et al., 2008: 4).

Public space (narrowly defined) "*relates to all those parts of the built and natural environment where the public has free access. It encompasses all the streets, squares, and other rights of way, whether predominantly in residential, commercial, or community/ civic uses; the open spaces and parks; and the 'public/private' spaces where public access is unrestricted (at least during daylight hours). It includes the interfaces with key internal and external and private spaces to which the public has typically free access"* (London Assembly Planning and Housing Committee, 2011: 47).

The debate on defining access rights in public spaces is essential. Public space has usually been defined in terms of accessibility and ownership (Figures 2.2-2.7). Many other sets of criteria should be considered in terms of defining public space. These terms must include **ownership** (publicly owned or privately owned), **accessibility** (availability of public transportation, opening hours), **location** (horizontal, vertical, in centre, away from city centre), **typology** (streets, plazas, squares, parks, 'skycourts', 'skygardens', shopping malls, etc) **spatial characteristics** (open, semi-open & enclosed) and **activities** (list of the things and opportunities you can do in the space) (Williams & Green, 2001; Carmona, 2010; Zhang & He, 2020).

Figure 2.2. Trafalgar Square, London Source: Author

Figure 2.3 Russell Square London Source: Author

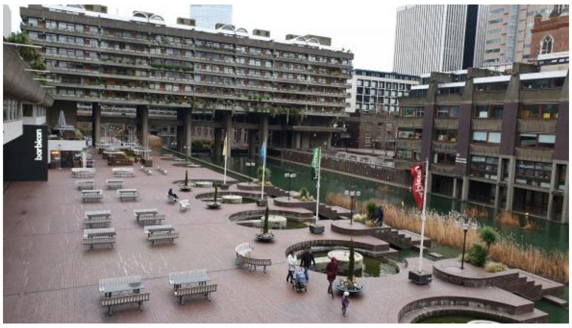


Figure 2.4 The Barbican, London, Source: Author

Figure 2.5 More London, London Source: Author

Figure 2.6 Sky Garden, London, Source: Author

Figure 2.7 The Garden at 120, London Source: Author

2.3 The History of London's Public-Private Spaces

For nearly two thousand years since Roman origins at the Thames crossing, London was mostly on the north bank of the river, on better building land, enclosed by the city wall on three sides and to the south, the natural barrier of the river. For centuries, the only crossing of the Thames was the original London Bridge, a 'linear town' of occupied buildings and market spaces, until its replacement 1831. London has enjoyed an immense heritage of public spaces. The crowded city on the north bank included pathways, market places, ropewalks, slaughter places, even places of execution; in the Georgian era, London expanded, to include formal streets and public squares, including green spaces. Villages in the region merged to become Greater London. Historically, there has been a good tradition of planting trees along streets in London (Perring, 2015; Ijeh, 2020; Fraser, 2021).

In the decades since post-WW2, the rebuilding of London, there has been a shift in developers' attitudes regarding the ownership and management of existing, new and future public spaces. Large developments replaced grid-street neighbourhoods of Victorian houses (in the name of ‘slum clearance’ or ‘bombsite regeneration’ or ‘parcelling land’), putting the land under one ownership (Hagan, 2019; Carmona & Wunderlich, 2013). Privatisation of space has become more ‘total’ since 1980. Prior to 1980, most squares, parks, green spaces, and streets were adopted by local authorities which allowed for more openness and opportunities concerning activities and public use (Punter, 1990; London Assembly Planning and Housing Committee, 2011)

The 1980s and early 1990's were a period of privatization, disinvestment by local and central government, and decline in the city's publicly-owned streets and places, which were largely seen as traffic arteries and car storage spaces (Minton, 2006; Punter, 1990). A major shift occurred in 1990 when planning and design specialists designated the new ‘Canary Wharf’, the regeneration of London’s docklands as one large business district estate. Local authorities found it difficult to keep up with public standards as budgets grew tighter (London Assembly Planning and Housing Committee, 2011; Loftman & Nevin, 1995). However, developers started seeing the quality and management of public spaces as crucial to the success and value of their sites. The developers need the public for work, shopping and living, and have the law backing up their private prerogative to enact private regulations (Madanipour,1999; Carmona et al., 2008; Carmona & Wunderlich, 2013).

The developers often have different objectives and priorities. It’s a complicated task to find a suitable balance of those priorities for any new public space. A developer’s first principle is to achieve a good square ‘footage’ of lettable buildings on the site (Németh, 2009). The space taken by a single swivel chair in an office building costs the office tenant £85 per year at 2022 levels. Developers who are focused only on office rental income do not see the space between or under the buildings as a direct earner of revenue. Lacking in a wider vision, they would prefer the space to be closed off (Bodnar, 2015; Minton, 2006).

The enlightened developer can be persuaded by their professional advisers and the city government (through advice or regulation) that including landscaping, break-out green spaces or a green sky-court can bring a significant advantage to all parties: the developer, the public, and the city. With good marketing, the brand image of the development is enhanced, and the global rental income of the lettable office spaces can be higher; developers can be persuaded that some public space is important as part of the network of public urban routes and spaces (Yeang & Richards, 2007; Pomeroy, 2013). Walk-through public space has a direct revenue earning ability through the higher floor rental of retail and hospitality businesses, with a good 'footfall' (Leclercq & Pojani, 2021; Németh & Schmidt, 2011).

As a result, many London redevelopment projects incorporate spaces that are accessible to the public but are not necessarily 'public' in legal terms (Madanipour, 2019; Carmona, 2010; 2022). Privately managed spaces usually have a separate set of regulations from public areas. Developers commonly think that they will possess and control any open space, with full power to increase the value of their building project (Carmona, 2019; Huang & Franck, 2018). When legal agreements are negotiated, success hinges upon alignment with a Master Plan and the deliberations during the early stages of seeking planning permission (De Magalhães & Carmona, 2009; Madanipour, 2010).

The former Mayor of London said that *"There is a growing tendency towards the private management of publicity accessible space where Londoners can feel excluded from parts of their cities"* (Johnson, 2009: 8).

Different experts have reached distinct conclusions about the privatization of public spaces in London. They discovered that people's 'right' to access these areas is being replaced by a 'privilege' that can be granted, restricted, controlled, regulated, or withdrawn (Carmona, 2009, 2015). Some people welcome this shift and see it as a blessing, since they feel safer and benefit from the regular maintenance and management of the space, even though they are yielding up ancient rights. Others, on the other hand, seek to take risks in order to retain the civic significance of local character of the streets and public spaces, in case too much regulation might transform the public realm into an unvarying lifeless environment if too tightly controlled, and if commercial management is imposed (Bodnar, 2015; Carmona, 2019). The private sector does not usually share the assumption when they take control of public space (London Assembly Planning and Housing Committee, 2011).

There is a segregating guideline between public and private areas in London. Some critics contend that the proliferation of 'private-public' spaces produces over-regulated, sterile places that are disconnected from the local area and its residents (Madanipour, 2010, 2019). However, there are some examples of well managed private-public spaces: safe, popular, and vibrant areas, where previously people would not have thought of going. One of these examples is Bermondsey Square in south London, which won an award in 2011 as the 'best new public space' (Figure 2.8). On the other hand, there are several instances where public usage and access have been restricted, or where new private development of public spaces is linked with strict management. In West London, security guards have previously prevented photography even when individuals were photographing each other in the area at Paddington Basin (Figure 2.9). In Canary Wharf, East London, similar strict rules are applied by security guards (London Assembly Planning and Housing Committee, 2011).

Figure 2.8. Bermondsey Square, South London, Source: https://bermondseysquare.net/

Figure 2.9. Paddington Basin in West London, Source: Laura Dosa, https://www.flickr.com/photos/153873724@N07/36641366276/

The increase of consumption and opportunities to consume might narrow the range of the public visiting public spaces, especially if there is an entry fee, turnstiles, elevators or other restrictions to access these private-public spaces (Devereux & Littlefield, 2017; Minton, 2006). Hagan declares that, if the built environment of cities continue to be controlled and managed by the private sector, all cities need a 'bill of rights'; that would require the private sector to manage their public space in such a way that is nearer to being truly public and inclusive (Hagan, 2019). The Greater London Authority (GLA) is exploring the idea of protecting public space as a part of the new London plan, which is the mayor's spatial strategy for the city. The GLA's 'Public London Charter' sets out both rights and responsibilities for users and owners of public spaces, regardless of whether these were run by the city council or in the hand of private developers (Carmona, 2022).

2.3.1 London Garden Squares

London's garden squares are set into a formal grid of broad streets of elegant town houses, serviced by mews streets (formerly for transport, horse-storage, servant housing), and green squares full of trees and lawns, enclosed by iron railings, with metal gates (Goodman, 2003). The history of London's garden squares, notably those of the Georgian era, demonstrates how these places were not intended to be public spaces but rather as private gardens for the adjacent housing, whose facades enclosed the square (Lawrence, 1993; Carmona & Wunderlich, 2013). The 16th to 18th centuries were the golden age of London squares (Figure 2.10 and 2.11). They represented an early manifestation of social separation and privatized domestic open areas (Jacques, 2017). This formal urban order of streets and gardens also appeared in great shipping cities like Boston USA, Bristol and Liverpool UK, benefitting from the wealth of the growing Empire and Atlantic trade (Smith, 2005).

These garden squares are one of the first practical ways to bring and formalise elements of the natural environment into a cityscape. In the beginning, the garden squares were not designed to be green spaces for relaxing. They were formal hard piazzas to offset the elegant facades that surrounded them. They were mainly used for parking carriages, for resting, watering and feeding horses, with the insufficiency of space in back gardens (used for vegetable cultivation) in the grand houses that surround them (Goodman, 2003). These hard landscaped open spaces were transformed into a green-filled town-scaled parks, inspired by the fashionable 18th century landscaping of great estates like Stowe, Blenheim and Hampton Court Palace (Carmona & Wunderlich, 2013). The first London garden square was designed to provide comfortable safe outdoor recreational space for the wealthy individuals of the grand townhouses who could enjoy light, ventilation, and vistas while residing in the metropolis (Felus, 2016).

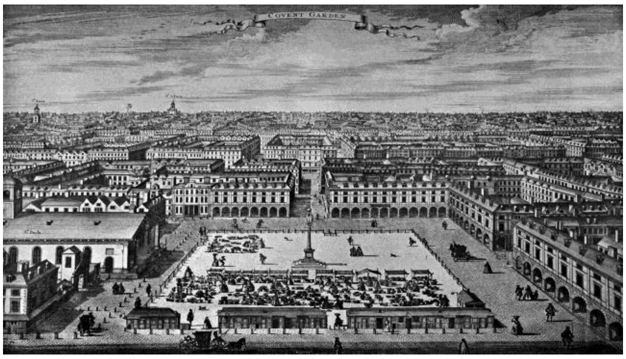


Figure 2.10. Covent Garden by Sutton Nicholls, 1720, Source: Westminster City Archives

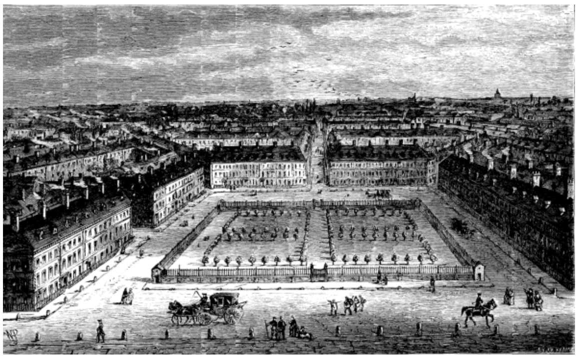


Figure 2.11. Red Lion Square 1800, Source: https://www.british-history.ac.uk/old-new-london/vol4/pp545-553

The increasing number of London garden squares during the 17th-18th century was acknowledged as England's most significant contribution to European town planning (Felus, 2016). During the eighteenth and the nineteenth-centuries, other town and cities in Britain were following the pattern, most notably those of Liverpool, Bath and Edinburgh. London squares were only controlled and accessed by a simple post and rail fence. Antisocial behaviour increased because there was no control over who could access these squares, making them unusable by the privileged classes, whose houses looked on at them.

By the end of the eighteenth century, the erection of metal railings had been established to control access. The residents of the squares often initiated the process of enclosing the square, and not the landed freeholder (Lawrence, 1993). The transformation of London squares during the eighteenth and nineteenth centuries can be viewed as a critical chapter in the evolution of city development. Over the decades, they became increasingly exclusive, and became more green, with lawns and trees. It seems clear that London gained these airy green spaces by establishing the rights of the house-owners, and were not conceived to be for Londoners at large (Carmona & Wunderlich, 2013) .

London's garden squares underwent a dramatic change in the late nineteenth century when the Metropolitan Public Gardens Association (MPGA), was founded in 1882. Birkenhead Park had already been created in 1847 as a pioneer of the idea and the physical and legally protected reality of public parks in cities and municipalities. It was laid out by Joseph Paxton on marshy grazing land, and enhanced by water-features, pavilions, and bridges (Eisenman, 2013; Lee & Tucker, 2010). Hyde Park in London has existed as a hunting ground for the King since 1536, partially open to the public since 1637, and became a public park as we now know it in 1851 for the Great Exhibition (Larwood, 1881; Rabbitts, 2015). These inspired cities around the world to follow, such as New York's Central Park in the 1850s.

MPGA aimed to change London's garden squares into accessible public parks for all citizens (Sakai, 2011). The First and Second World Wars had a large impact on these changes; during wartime, many of the iron railings were removed and recycled as armaments, while air raid shelters and vegetable allotments were being erected on the space. Consequently, formal maintenance of these gardens decreased which led to more overgrown and more naturalized planting (Malchow,1985). By the beginning of the twenty-first century, restoration efforts on the garden squares included returning their metal railings to keep people out at night, while many of them are publicly accessible by the day (Carmona & Wunderlich, 2013; Lang, 2020; Minton, 2012).

Whether public or private, London's garden squares remain as one of London's most striking urban characteristics and a joy for residents, citizens, and visitors (Figure 2.12 and 2.13) (Longstaffe-Gowan, 2012). The elevated social spaces in today's high-density city could be as beneficial for the health of the workers and residents as were the London garden squares (Raji et al.,2015). It is a matter of optimistic speculation that several decades in the future, some of the new elevated spaces discussed in this study will inspire the same affection for the public and visitors.

Figure 2.12. Eaton Square, London, Source: Author

Figure 2.13. Russell Square, London, Source: Author

2.4 London Urbanisation Challenges and the Need for Vertical Urban Spaces

London, as one of the world's leading global cities, faces a range of urbanisation challenges, including rapid population growth, housing shortages, traffic congestion, and air pollution. These issues, coupled with the constraints imposed by the Green Belt, necessitate a re-evaluation of the urban environment to accommodate the city's expanding population in a sustainable and healthy manner. Vertical urban spaces have emerged as a potential solution to address these challenges, promoting higher-density development and maximising land use efficiency. This section explores the issues associated with urbanisation in London and discusses the potential benefits of incorporating vertical urban spaces into the city's development strategy, with a focus on enhancing the public realm, preserving sightlines, and creating accessible green spaces within the increasingly dense urban environment.

2.4.1 The Development Cycle

The London public realm has long been diversified in terms of use, management, and ownership. However, there has been a recent resurgence of huge urban development projects, many of them parcelling together small single sites to form a new complex of offices, retail or mixed use (Sallis et al., 2016; Robinson et al., 2021) Typically, these have been driven forward by single developers and consortia who have progressively kept control of vital areas (Minton, 2006, Schmidt & Németh, 2010). Whilst this may be seen as a shift to more privately owned and managed places, in reality, many of these locations were never part of the public domain. Often, they were severely blighted small neighbourhoods and only occupied by small businesses, obsolete industries or individual tenant householders that did not have other options than to ‘go with the flow’. The developer with the vision to package a group of blighted properties and to present a visionary proposal earns the prerogative to negotiate with the city how much public access will be offered or permitted. (Devereux & Littlefield, 2017; Hagan,2019; Carmona, 2015).

Since 1990, London's population growth has been growing more quickly, not by birth rate but by urbanisation, the process of inward migration because of the financial magnetism of the capital. Two-thirds of the total increase happened in the second half of the three decades since 1990 (Zhang, 2016). This means that London's infrastructure and Planning policies need to be able to support this growth sustainably (Dianati, 2017). According to estimates from the Greater London Authority (GLA), by 2050 there will be 3.1 million more people living and working in London than there were in 2011 - an increase of 37%. This would take the city's population up to 11.27 million (Greater London Authority, 2019; Lu et al., 2018).

2.4.2 Health and Congestion

According to recent reports by researchers from King's College London, nearly every year, 9500 Londoners die prematurely as a result of polluted air (Walton et al., 2015; Pultarova, 2017). The main contributor is traffic congestion, which adversely impacts Londoners' daily lives – citizens with vulnerable health conditions are advised to wear air mask filters while travelling and walking around central London (Vaughan, 2015). Clearly, London's success has become its downfall; the challenge facing the city's government is whether it will prioritize the economy over the health and lives of its citizens. The London Congestion Zone since 2003 has made London safer for pedestrians and citizens with health conditions, compared to previous times, when the coal dust and fog induced 'smog' of the 1950s could be listed as a cause of death (Font et al., 2019; Brimblecombe, 2012). There is a social contract, as evidenced by the sequence of mayoral elections (approving and extending the Congestion Zone policy of Messrs Livingstone, Johnson, and Khan), that the public recognise the health and safety benefit of the zone more than the individual freedom to park a car in front of their favourite shop.

2.4.3 Housing in London

From 2015 to 2036, the GLA Housing Market Assessment found that London will need 49,000 to 62,000 homes each year to catch up with demand (New London Architecture, 2015; Mace et al.,2016). However, London is not building enough homes to support this growing population and meet its economic potential. To solve this problem, London needs a significant increase in house building, and a more rigorous requirement from developers for the ratio of social and affordable to luxury housing. More and more Londoners are struggling to find affordable homes that meet their needs as prices continue to rise (Snelling et al, 2016; Whitehead & Goering, 2021). As the GLA's following diagrams show (Figure 2.14), housing targets have increased in London over the past 40 years, but there has been no corresponding increase in house building. In fact, there has been a massive annual shortfall of houses built against targets (New London Architecture, 2015; Watt & Minton, 2016).

Figure 2.14 Annual housebuilding shortfall against targets, Source: GLA, DCLG

2.4.4 The Green Belt (GB)

The discussion about the London Green Belt (GB) has grown increasingly contentious in recent years. Many people view it as an essential policy that prevents urban sprawl; others believe it is a cause of the housing shortage and density. The Green Belt has a very long history. Even in the 16th Century, (the time of Queen Elizabeth I) there was concern about the growth of London, that it was sprawling and getting too large. Green belt history goes back to the late 1800s. The initial idea for the green belt was to bring green and open space to Londoners (Amati, 2007).

The idea became a reality in the 1920s for the first time. The main aim of the Green Belt was voiced as being to limit the growth of the built area of London, and to build 'new towns' and settlements outside the green belt, accessible by the rail network and a new set of motorways (Amati, & Yokohari, 2006; Amati, 2007). The idea of new towns began in 1898, and there were notable examples before 1940, such as Welwyn and Letchworth. The New Towns Act of 1946 formalised the process of moving population out of London into new towns.

The real significant period for the Green Belt comes in 1950 till 1955 under the Minister of Public Buildings and Works, Duncan Sandys, who encouraged the development of the GB as a nationwide policy for British cities (London School of Economic, 2016). The idea is now widely accepted in British cities, including the East Midlands examples of Nottingham, Leicester, and Derby.

As identified by the National Planning Policy Framework, there are five key purposes for implementing a Green Belt. The most important of these is to prevent large urban areas from expanding unchecked, with the convenience of the motorcar. Other objectives include preventing neighbouring towns from merging, assisting with urban regeneration within established centres, preserving historic townscapes and safeguarding rural areas from development into 'dormitory towns' (London First & Quod SERC at LSE, 2015; Frith et al., 2007).

The 'Metropolitan Green Belt' is seen as one of the main reasons why the land supply in London is very constrained (Mace et al., 2016). Many people would disagree with the GB policy, as they think that it was partially responsible for the high rents they have to pay. A more likely culprit is the abolition of rent controls, the loss of council housing through 'right to buy', and the immense magnetic attraction of London for work. The rise in rental costs forced more people into shared or sub-standard accommodation and forced people to commute longer distances to work (London School of Economic, 2016; White, 2016).

London's original North Circular and South Circular roads, built in the early motorcar age and lined with shops and houses, were easily overwhelmed by rapid urban growth. The GB was a way of defining a limit to physical urban growth. The M25 Motorway, (1975-1986) encircles London through the line of the Green Belt. The M25 is a physical concrete structure in the present day, more clearly and permanently defining the perimeter of London than the random but fortuitously connected areas of agriculture, woodland and green spaces that were in the Green Belt (Gant et al., 2011).

However, as industry moves out of London and leaves vast areas of land that can be recycled, there equally good arguments for 'brownfield' development, with a higher density than suburbia, within the already built-up area of the city (Mace et al., 2016). The proponents see this as being vastly preferable to permanent settlements eating up the Green Belt. Many mining, dockland and obsolete industrial zones are now housing estates, retail or business parks and country parks. East London is a prime example (Edwards, 2013; Healey, 1995).

The London Green Belt (GB) was designated due to its location, not because of the land's quality or accessibility. The land in the GB contains a variety of uses and varies from stunning parks to abandoned structures (that predate the GB) on wasteland, that are perhaps capable of ‘rewilding’ (Amati & Yokohari, 2006).

The London Green Belt Review says that London should protect its precious gardens and picturesque open countryside, and that London must find a way to integrate the GB into planning for new homes that London requires (London First & Quod SERC at LSE, 2015; Gunn, 2007). It should only consider development in places that are near to existing and future transportation nodes, have desirable environmental or civic impacts. Ideally, it could better serve London's needs by supporting higher-quality sustainable residential development with genuinely accessible green space (London First & Quod SERC at LSE, 2015; Han & Go, 2019).

2.4.5 Tall Buildings, Sightlines, and 15 Minutes Walking

With the astonishing post-war growth of London as global financial centre, London's skyline has visibly changed in recent years to accommodate the growth of tall buildings. According to the London Survey 2020, a record number of 60 tall buildings were completed in 2019 despite the political uncertainty caused by Brexit (New London Architecture, 2020). The ‘tall buildings pipeline’ including those in pre-planning, planning, and construction, remains strong at 525 buildings - only 3% lower than 2018. However, in the 2020s, the construction of tall buildings has notably slowed down and is at its lowest since 2015. The majority of buildings over 20 stories are located in central London, but there is a growing number of schemes planned in the outer boroughs which make up 35% of the total. This shift aligns with the need for Outer London Boroughs within the perimeter of the Green Belt to increase their population density to prepare for London’s required growth (New London Architecture, 2020).

Historically, London was monocentric with the highest buildings around the City of London. In the modern era, London is polycentric, with vertical growth nodes permitted around prime transport locations: Waterloo; London Bridge; Elephant and Castle; Canary Wharf; Canning Town; Blackfriars; and several more (Ahlfeldt & Barr, 2022). The sightline policy idea (‘Protected Views’) has been to have a height limit on much of the city, to give a consistent urban skyline with dramatic clusters at the nodes, and long-distance sightlines between the clusters. The first purpose was to preserve views of St Pauls, Greenwich, and other historic landmarks (Markham, 2008; Kufner, 2011; Naldi, 2019).

The sightline policy has produced further advantages: these clusters represent not just height but greater intensity of activities and population. This produces a more rational relationship between transport density and building density, putting the largest concentrations of people within 15 minutes' walk of primary public transport (Moreno et al., 2021).

That justifies a matching policy to ensure that there is a proportional ratio of elevated social spaces (or opened-up ground floor plane below or around tall buildings) to meet the recreational needs of the increased working and residential population in the clusters. The city and boroughs can work with developers to maintain a reasonable proportion of accessible public space within 15 minutes walking, as has been achieved with Crossrail Place in Canary Wharf (above), the Sky Garden in Fenchurch St (above), and Leadenhall Tower in the banking district (below).

The 21st century shift in patterns of working means fewer centrally located office buildings, and more people wishing to have homes closer to the centre. The new residents wish to reduce the cost of commuting, and to participate in the vibrancy of the city. The widely (and globally) recognised '15-minute city' concept aims to plan for residents and workers to be 15 minutes' walk from their immediate needs and a green space, and to a transport node that will take them to what they need if it is further (Pinto & Akhavan, 2022; Pozoukidou & Chatziyiannaki, 2021).

2.4.6 Green Spaces in Former Business Districts

New office buildings have rigorous limits placed on the amount of car parking permitted, in order to encourage (indeed, compel) walking and public transport. Thus, the majority of London's new high-rise buildings are residential, with a strictly limited permission for the number of private car parking spaces. Redundant office buildings, with strong frames, cores and daylighting, have been converted to residential in preference to demolition (e.g. Southbank Tower). It is predicted that the new wave of residential buildings and conversions will supply 110,000 additional dwellings to meet a significant portion of the city's housing needs (New London Architecture 2020). Furthermore, there has been an increasing demand for more diverse development and a more holistic approach to mixed-use plans, including the need for access to green space.

City centre business districts (e.g. London, Chicago, New York financial districts) used to be ‘ghost towns’ at weekends, with no residential population, and a lack of hospitality venues for the evening trade. As cities become denser and more lively with new business and residential developments nestling closely, tall building design needs to be increasingly considered in relation to intricate urban contexts, serving the public, not just office workers at lunchtime. Hybrid (mixed use) buildings with vertical access for the public are now seen as having the potential to be regarded as a vertical extension of the public realm (Cho et al., 2015).

Continuing the evolution of London as a skyscraper city, including residential inhabitants, the last decade has witnessed an increasing trend for urban spaces in the sky. This new phenomenon has been designed and tested in a number of completed projects, such as the Sky Garden (indoor garden) at 20 Fenchurch Street, The Garden (outdoor garden) at 120 Fenchurch Street, and the 300 metre long Crossrail Place (semi-indoor, semi-outdoor garden) at Canary Wharf. As these spaces become part of the City’s public space offer, the debate continues about whether these innovative places can become vibrant and truly public urban spaces.

2.5 London Public Charter

“Public spaces should be places that all Londoners - regardless of age, disability, gender reassignment, pregnancy and maternity, race, religion or belief, sex or sexual orientation – can enjoy and use confidently and independently, avoiding separation or segregation” (Khan. S, The Mayor of London, 2020).

An inclusive environment is not only about the physical design, but also the management and rules that determine access. How a public space is governed plays a big role in how it is used and perceived. Rules concerning behaviour should be limited to those deemed necessary for safe management (Wilson & Moore, 2020).

Sadiq Khan, the Mayor of London at the time of writing, has committed to creating a public London charter in the new London vision and plan, embracing the notion of the 15-minute city. The charter aims to serve as a guideline for the creation of public spaces in new developments. The new London character outlines eight principles for private property owners, managers, and users to follow, in order to achieve the goals of the city plan. It calls for landowners to advocate and promote the use of public space by all communities, urging them to provide the greatest degree of public access, regardless of ownership (Carmona, 2019, 2022).

2.5.1 London Public Charter principles

The principles of the London Public Charter, as outlined by Sadiq Khan, the Mayor of London at the time of writing, set a roadmap for the creation and management of public spaces in London. These guidelines not only encompass the physical aspects of public spaces, but also touch upon the legal, social, and administrative aspects that can influence how these spaces are perceived and utilized by Londoners and visitors alike. The eight principles - Public Welcome, Openness, Unrestricted Use, Community Focus, Free of Charge, Privacy, Transparency, and Good Stewardship - aim to create a cityscape that is accessible, inclusive, and enjoyable for everyone, regardless of their background or circumstances. This is in line with the vision of the 15-minute city, where all necessary amenities are within a 15-minute walk or cycle. Through these principles, the Charter underlines the importance of equal access, unrestricted use, respect for privacy, and responsible management in shaping the character of public spaces in the city.

1-Public Welcome

The first principle of the London Public Charter calls for all public spaces in London to be designed to be accessible and inclusive in a way that makes everyone feel welcome. Public spaces should be kept clean, well-maintained, and brightly lit, offer shade and shelter, places to sit and rest, as well as public facilities that correspond to local needs. According to The London Plan, this goal can only be accomplished by taking into consideration how people use the public space depending on the time of day or night, weekday or weekend, and seasonality throughout the year (Gould, 2022).

2- Openness

The physical layout of public space, as well as the way it is managed, affects its openness and accessibility. The London Plan urges authorities to evaluate how people utilize the public realm, as well as the many types, locations, and relationships between public spaces in an area. This will help in understanding where are the deficits for certain activities, or barriers to movement that cause separation. Public space should be open and provide the greatest amount of public access, that is reasonable and feasible. It should be treated as a part of London's continuous public realm, regardless of land ownership (Carmona, 2019; Madanipour, 2019).

3- Unrestricted Use

The prime rules that should restrict public behaviour in space are the ones essential for safe management of the space at different times of day and night. Allowable uses in a public space may include activities such as non-commercial photography; peaceful political activities like canvassing, rallies, or single event/day demonstrations; following the ‘Busk-In-London Code of Conduct’ while performing musically; walking dogs; cycling safely; skating; and consuming food and drink (including food and drink that users bring into the space themselves) (Minton, 2006; Carmona, 2022).

In research conducted by Bosetti, et al. in 2019, it was shown that the most regulated public spaces in London are those that are owned and managed by commercial landowners (Bosetti et al., 2019) This 'corporatisation' of outdoor areas can cause Londoners to feel excluded from their own city, as well as creating a feeling that rules surrounding behaviour are weighted too heavily towards regulation rather than enjoyment. In an ideal world, users should be free to move through these areas, take part in activities or rest and relax without causing disruption to others (Gould, 2022).

4- Community Focus

Public spaces should be designed to enable people to interact and socialize with one another, as well as enjoy their community (Peters et al, 2010). According to The London Plan, developments should include a public realm that is inviting and provides opportunities for social activities, formal and informal play, and social interaction during the daytime, evening, and night where appropriate. In addition, provisions should be made for community-led cultural activities that reflect the diversity of London’s communities, as well as public artworks or other methods of celebrating diversity in the public realm (Wall, 2022; The Mayor of London, 2016).

5- Free of Charge

Primarily, public spaces should be open to the public without a fee. Ticketed events that might block access or impact enjoyment for other users should be announced in advance with enough time for people to make alternate plans (Huang et al.,2020; Carmona, 2022). The amount of free versus ticketed/commercialized activities done in public spaces needs to take into consideration everyone's needs, not just those of the local community, but also any visitors who come from further away. Free events that are co-produced with the community and managed well can significantly increase people’s enjoyment of public space and identification with it. These sorts of events should be encouraged (The Mayor of London, 2020; Keller, 2009).

6- Privacy

Managers and landlords of public places should take care to preserve the anonymity and property rights of all users. CCTV and other data harvesting technologies should be used for public safety and security, only where necessary for these purposes. Protecting both people and property is a necessity, thus landowners and managers of public areas should be clear about the aim of any data gathering (Moreham, 2006; Reidenberg, 2014). These rules and regulations should secure people and property in a manner that is both lawful and in accordance with regulatory standards, rather than being used merely for biometric information (The Mayor of London, 2020; Marcus & Francis, 1997; Carmona et al, 2010).

7-Transparency

Without clear, written rules for public spaces, it is difficult to hold anyone accountable. This problem persists because there usually isn't any public engagement or consultation when private landowners set rules for these places (Carmona, 2019; Nanz & Steffek, 2004). The result is that people are largely unaware of what they can do in these spaces and security staff have a lot of discretion over enforcing the rules. The lack of communication may lead to security staff exceeding their authority ‘just because they can, and the safest thing is to say NO!’, without comprehending other people's viewpoints, the details of their employer’s regulations, and how rules might impact them. The Public London Charter should have prominent notice of compliance. Users should have free access online and onsite to the charter's ideals as well as information about the space's owner and management firm, as well as any applicable regulations (Carmona, 2022; Madanipour, 2019).

8- Good Stewardship

Good stewardship that is both mindful and considerate of regulation leaves people with a better impression of public spaces, regarding how enjoyable, accessible, and welcoming they are. People who live in London tend to feel that some areas which are supposed to be open to the public seem more like private property, because the density and demeanour of security guards or signage makes it seem restricted (Minton, 2006; Devereux & Littlefield, 2017). Public space should be managed so that it is accessible and welcoming to all Londoners and visitors. Supervision of public spaces should be informal and considerate of the people who use them. Maintenance activities, as well as any enforcement of temporary restrictions on the use of public spaces, should be reasonable. Staff engaged in supervisory activities related to public spaces should receive appropriate training (Németh & Schmidt, 2011; De Magalhães & Carmona, 2009).

2.5.2 London Public Charter Framework

The London Public Charter for Public Spaces provides a framework for the preservation and enhancement of public spaces in the city, and it helps to ensure that public spaces continue to play a vital role in the city's cultural, social, and economic life (Table 2.2). By following the principles and goals of the charter, London can maintain its status as a vibrant and dynamic city, where public spaces are accessible, sustainable, and inclusive (Carmona, 2022; The Mayor of London, 2020).

Table 2.2: London Public Charter Framework. Source: Author.

Framework & Guidelines	
Accessibility	Public spaces should be accessible to all people, regardless of their socio-economic status, and they should be designed to meet the needs of people with disabilities.
Sustainability	Public spaces should be designed and managed in a way that is sustainable and environmentally responsible.

Community Engagement	Public spaces should be designed and managed with the active involvement of the community, and they should reflect the cultural and social values of the city.
Cultural Heritage	Public spaces should be designed and managed in a way that preserves and enhances the city's cultural and physical heritage.
Economic Vitality	Public spaces should provide a platform for economic activities that contribute to the city's economic growth, while also preserving and enhancing the city's cultural and social life.

2.6. Chapter Summary

In this chapter, the term of 'private public space' has been examined and redefined based on existing theories in the literature. Private-public spaces in London are becoming increasingly prominent, as they offer a number of benefits over purely public spaces, such as increased security, privacy, and a high level of maintenance. However, the publicness of private-public spaces in London is under threat due to the growing trend towards complete privatisation. This has led to a reduction in the amount of public space available in the city, and has contributed to the commercialisation of public spaces. This has important implications for the city's cultural and social life, as well as its economy, as it may limit the ability of people to access and enjoy public spaces.

The London Public Charter for Public Spaces was developed to ensure that public spaces continue to play a vital role in the city's future. The charter was created through a collaborative process involving government agencies, non-profit organizations, and community groups. It outlines a set of principles and goals for the preservation and enhancement of public spaces in London, and it provides a framework for the responsible management of public spaces in the city.

This chapter provides a solid background and foundation for this study about the emergence of this new typology of elevated urban spaces in London. In conclusion, the literature review on the history of London's private public spaces, the London urbanisation challenges and the London public charter provides three significant insights. First, there is value in creating distinctive elevated urban spaces in the high-density city; these are crucial for mental and physical health, but face many and various urban challenges that threaten the configuration and performance of public spaces in the city. Secondly, the nature of inclusive vertical public realm in the city is a complex and versatile phenomenon that need to be studied and interpreted through the perspective of experience to get a thorough understanding. And thirdly, for the future, there is a need to identify the critical factors and challenges in design and management for creating new elevated social spaces. These all need to be considered and will be analysed in the coming chapters.

Chapter 3: Hybrid Urban Spaces and Elevated Social Spaces: Global overview

3. Introduction

The primary objective of this thesis is to examine the challenges, limitations, and opportunities related to elevated social spaces in London, particularly considering the evolving social, public health, and mental health requirements in a post-Covid and future pandemic context.

Chapter 3 of this thesis serves as a literature and contextual review of elevated social space design, focusing specifically on the post-Covid and future pandemic context. This chapter addresses various themes, including density and hybrid urban spaces, the history of vertical urban spaces, biophilia, the freedom to roam, view and breathe, and their contribution to promoting mental health. A particularly noteworthy precedent highlighted in this chapter is Singapore's approach to designing vertical green social spaces, which involves an in-depth analysis of Singapore's implementation of vertical public realm design and place-making in the sky. Furthermore, this chapter will examine the design of sustainable elevated green social spaces from a macro-scale, offering a global overview timeline and different approaches, to the micro-scale, concentrating on London, which is the main focus of this study.

Drawing upon an extensive overview of relevant literature and global precedents, this chapter offers insights into the design quality of vertical urban spaces. Key aspects for assessing these spaces within the context of this thesis include accessibility, publicness, activities, circulation, biophilic offerings, design, and management. Moreover, it is crucial to contemplate the impact of the Covid-19 pandemic on their design and the potential influence of future pandemics on the design of elevated social spaces (Figure 3.1).

Ultimately, this chapter aims to contribute to the discourse on the design of elevated social spaces and its potential to support the physical, mental, and social wellbeing of individuals in an ever-changing urban environment.

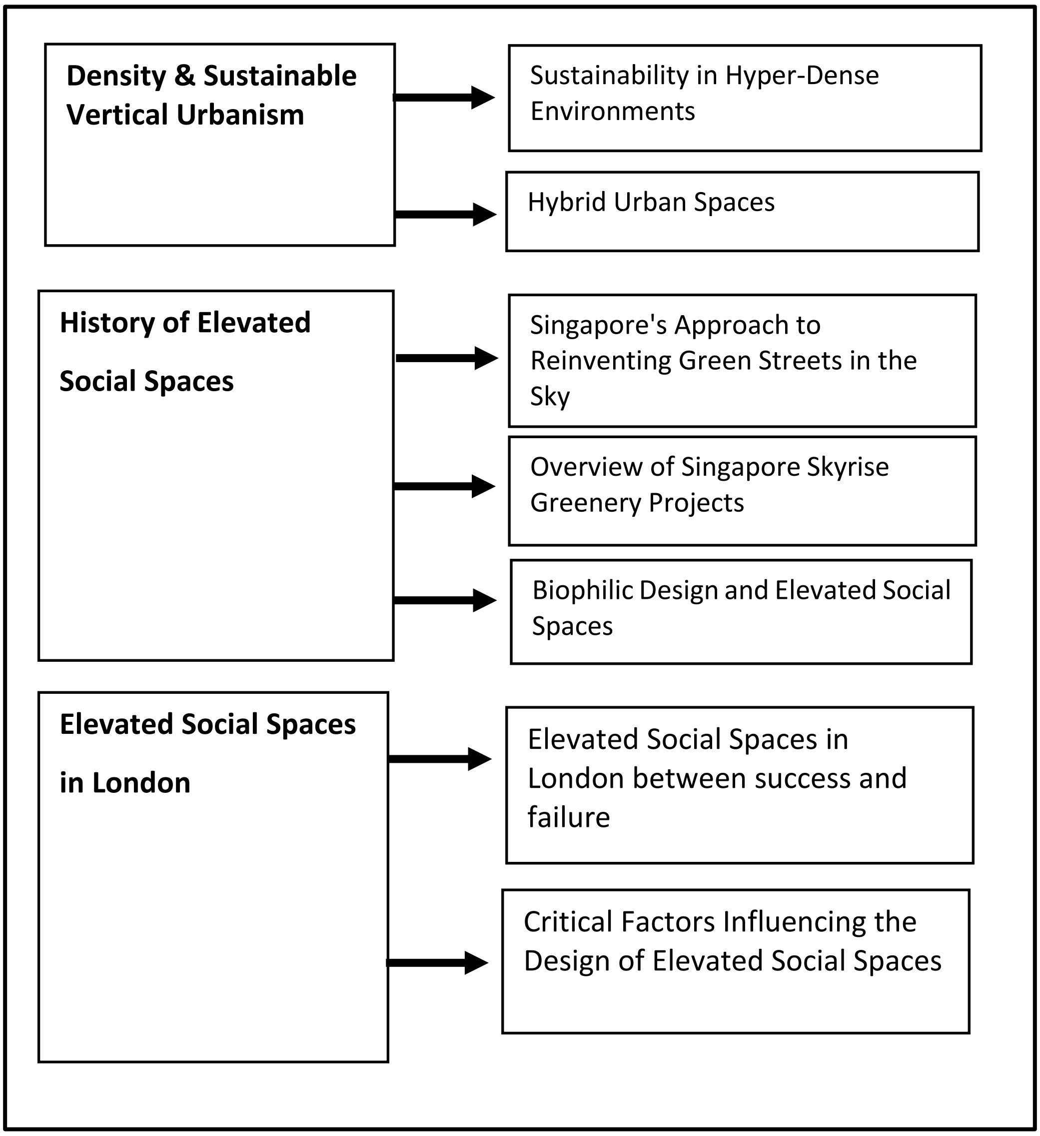


Figure 3.1: Diagram illustrating the primary sections covered in Chapter 3. Source: Author.

3.1 Density & Sustainable Vertical Urbanism

The dawn of the 21st century has been characterised by a remarkable upsurge in global urban population and the process of urbanisation. Present-day data reveal that, since 2007, over half of the global population resides in urban locales (Desa, U.N., 2015). According to the United Nations World Urbanisation Prospects Report (2014), 54% of the world's populace inhabit urban regions, a figure projected to escalate to 66% by 2050, thereby encompassing over six billion individuals. This burgeoning growth rate approximates a weekly increase of 1.4 million people, equivalent to the population of London every six and a half weeks (Leeson, 2018; Oldfield, 2019).

The postulate that urban environments should manifest elevated population density and compactness while simultaneously maintaining habitable conditions for their residents is a widely endorsed tenet; indeed, it constitutes a core philosophical principle of the Council on Tall Buildings and Urban Habitat (Al-Kodmany, 2018; Wood & Henry, 2016). Nevertheless, metropolises worldwide are each endeavouring to attain this objective through their distinct methods, resulting in discrepancies in determining the suitable equilibrium and optimal benchmarks for sustainable urban form requirements concerning density, transportation, and mixed-use functionalities (Lehmann, 2016; Bibri, 2020). As Talen (2011) observed, attempts to formulate a concrete strategy to achieve this balance have been infrequent and relatively sparse.

Proponents of compact or highly compact urban models posit that such spatial configurations lead to multiple benefits, including decreased energy consumption, mitigated ecological footprints, diminished air pollution, and optimised transportation, infrastructure, and management costs (Bibri, 2020; Newman & Kenworthy, 1989, 1999, 2007). Consequently, these models are considered economically viable and integral to the future development of urban environments while simultaneously contributing to the conservation of agricultural and natural habitat land. Central to this perspective is the assertion that enhancing accessibility to services, facilities, urban transport nodes, and designating land for parks and agriculture fosters a sustainable and habitable urban milieu (Forsyth, 2008; Saelens et al., 2003; Zhang et al., 2018).

However, research has yet to establish a definitive consensus concerning the precise relationship between urban density and sustainability, with various factors, such as social equity and quality of life, warranting further examination (Masnavi et al., 2019; Zhao et al., 2017). Paramount to the potential arithmetical formulae are the considerations of climatic and cultural contexts; multitudes of individuals from around the globe possess diverse historical backgrounds, present conditions, and future expectations. This diversity is evident in the vast array of major cities, such as Los Angeles, Chicago, New York, London, Berlin, Abu Dhabi, Mumbai, Tokyo, Shanghai, Singapore, Jakarta, and Sydney, all of which are characterised by burgeoning populations but distinct histories, cultures, and contexts (Lehmann, 2016; Rubiera-Morollón & Garrido-Yserte, 2020).

The notion of density varies across cultures, with a specific number of dwelling units per hectare considered high density in one context, yet deemed low or medium density in another (Oldfield, 2019). Moreover, identical values of built and population density indices may materialise in divergent forms and scales within the built environment. For instance, high-rise neighbourhoods in Singapore and low-rise urban blocks in Amsterdam may possess equivalent floor area ratio (FAR) values, yet exhibit striking differences in their spatial configurations (Cho et al., 2015; Oldfield, 2019). This highlights the necessity to contemplate the cultural, geographical, environmental, and historical contexts underpinning a particular conception of density, which can bear significant implications for urban planning and design. Thus, delving into these intricacies is essential for establishing a more nuanced comprehension of density in diverse settings (Bayulken & Huisingh, 2015; Afrin et al., 2021).

Compact urban developments have been demonstrated to offer environmental advantages as well as bolster health and wellbeing (Mouratidis, 2019, 2021; Giles-Corti et al., 2022). Jane Jacobs, one of the earliest proponents of high-density urban living, recognised its potential to engender city vitality, safety, and a sense of community. Jacobs maintained that urban life can flourish at densities of approximately 250 units per hectare, a figure tenfold greater than that observed in suburban regions. She dismissed the idea that high-density developments inevitably lead to overcrowding, arguing that overcrowding stems from an excessive number of individuals per dwelling rather than density per unit area. In Jacobs' perspective, high density is a crucial element in fostering urban diversity and vitality, provided that there is variation in building character, form, and programmes, as excessive standardisation can inhibit vitality (Jacobs, 2016; Moroni, 2016).

The relationship between perceived density and crowding has been the focus of extensive research in the field of environmental psychology. According to Churchman (1999), perceived density is not only affected by physical factors but also by psychological, social, and cultural factors. On the other hand, crowding is characterised by negative emotional states such as anxiety and frustration and is associated with a range of adverse outcomes, including cognitive overload and reduced performance (Evans, 2003; Evans & Lepore, 1992). Although the terms 'density' and 'crowding' are often used interchangeably, it is essential to distinguish between them, as they have different psychological and behavioural implications (Stokols, 1972; Schiffenbauer et al., 1977; Regoeczi, 2002).

Stokols (1972) contends that 'density' and 'crowding' are distinct concepts and that density alone is not necessarily a source of crowding. Instead, crowding arises from the interaction between the environment and the individual, with factors such as spatial configuration, lack of personal private space, and economic pressure to share small spaces with family or strangers (Baum & Paulus, 1987; Regoeczi, 2008; Ashkanasy et al., 2014). These circumstances influence an individual's perception of density and potential for crowding. Certain individuals may be more sensitive to perceived density than others, and this sensitivity may be influenced by cultural and social factors, age, and gender, as well as individual differences in personality and cognitive style (Gifford, 2007; Kaya & Erkip, 2001).

In contrast, recent sociological and physiological research posits that the escalation of urban density engenders social disorder and psychological stress, jeopardising physical well-being and personal space (Oldfield, 2019, Evans et al., 2002; Gomez-Jacinto & Hombrados-Mendieta, 2002). Furthermore, contemporary studies have evidenced that the proliferation of modern high-density residential locales, particularly those comprising high-rise structures, diminishes the degree of serendipitous interactions among occupants, thereby facilitating a more arduous environment that encroaches upon individual privacy (Kellert et al., 2011; Al-Kodmany, 2018). As a result, the heightened demand for solitude instigates individuals to maintain greater distance and to eschew social contact (Bridge, 2002; Madanipour, 2003; Tonkiss, 2005).

An examination of two cities highlights the possible polarity of density and urban form. At one extreme, there is the low-rise, low-density city of Houston, with its high-rise Central Business District (CBD) and a sprawling carpet of suburbs, which has an average population density of 3,500 per square mile, all dependent on the private motor vehicle, surrounded by seemingly unlimited semi-desert land, gradually filling with an overlay of the suburban road grid (Qian, 2010; Cervero & Murakami, 2010). The obverse example is Greater Hong Kong (including the island of Hong Kong, Kowloon, and the New Territories), with a population density of nearly 93,000 people per square mile, with a consistently dense and high-rise pattern of city for living and working, all connected with mass transit, balanced with a vast area of green forests and hill country close by (Al-Kodmany et al., 2022; Yeh & Xu, 2011). Hong Kong has finite limits to its land area (unlike Houston), contained by the South China Sea, and the former border with mainland China.

It is worth noting that Houston in the US utilises 34 times the amount of land area and natural resources compared to Hong Kong. Greater Hong Kong is 27 times denser than Houston (Figure 3.2, 3.3, and 3.4). The extremes of Hong Kong's built form are balanced by the significant proportion of its territory being composed of forested country parks (Jim & Chen, 2006). This has led to considerable differences in terms of transportation and environmental sustainability. The people of Houston are heavily reliant on private cars, with resultant high levels of CO2 emissions, pollution, time lost, and mental stress from traffic delays (Brownstone & Golob, 2009). By contrast, the people of Hong Kong are able to rely on mass transit, walking, and taxis for transportation (Cervero & Murakami, 2010; Al-Kodmany et al., 2022). These statistics do not necessarily imply that all cities should strive for greater density and height; rather, they suggest that density can serve as a more sustainable model for building a vibrant city (Oldfield, 2019; Lee & Chan, 2008; Mahtab-uz-Zaman et al., 2000).

Figure 3.2. Houston & Hongkong Comparison. Source: TED Talk on Vertical Cities- Andrew Fons

Figure 3.3. Hong Kong walkway, Source: Wikimedia.org

Figure 3.4. Houston Suburbs. Source:.Houstonchronicle.com

Two prominent Chinese megacities, Beijing and Guangzhou, serve as striking examples of urban centres that have experienced a substantial transformation from historically low-rise environments to predominantly high-rise, monocultural cities (Lees, 2014; Chen et al., 2020). Critics argue that these cities are characterised by insufficient planning, demolition of traditional, high-density, low-rise neighbourhoods, and the adoption of grid-based land parcelling for the construction of high-rise buildings (Figure 3.5, 3.6, and 3.7). These alterations have considerably impacted the identities and vibrancy of the urban inhabitants. In the past, Beijing was a city that accommodated navigation primarily by bicycle or on foot, enabling individuals to traverse the urban landscape for work and leisure purposes. Presently, however, transportation in Beijing largely necessitates the use of private vehicles or taxis (Day et al., 2013; Al-Kodmany, 2018). For instance, a typical ring road in Beijing encompasses an 18-lane expressway, which poses a significant challenge for pedestrian accessibility.

Figure 3.5 -Beijing Urban transformation. Source: Daniel Winey

Figure 3.6-Guangzhou Urban transformation. Source: Daniel Winey

Figure 3.7 -Beijing's typical ring road. Source: Author

Insufficient planning, mismanagement, and unregulated density can result in severe issues, as exemplified by the now-demolished 'Walled City', a high-rise Chinese enclave in Kowloon, Hong Kong (Figure 3.8), with origins dating back to the Song Dynasty (960-1297) (Lehmann, 2016; Adams & Hastings, 2001). The uncontrolled density led to overcrowding, limited natural light, and inadequate ventilation at pedestrian level, exacerbating the urban heat island effect (Lai et al., 2018; Adams & Hastings, 2001). The compromised living conditions in the crowded, dimly lit flats, combined with the narrow streets that resembled airless canyons, had substantial health implications for the inhabitants. With a population density of 1.2 million per square kilometre, Kowloon's 'Walled City' was once the most densely populated area worldwide (Oldfield, 2019; Lehmann, 2016). Neither Chinese nor British authorities had implemented any regulations for the settlement, resulting in the emergence of a precarious, unregulated urban environment (Sinn, 1987; Lehmann, 2016).

Figure 3.8 Kowloon walled city, Hong Kong, Source: www.reuters.com

Academic literature has demonstrated that the concerns related to early high-rise residential designs have evolved from concentrating on the buildings' structural elements to encompassing issues such as substandard maintenance, inadequate social spaces, and a paucity of community facilities (Appold & Yuen, 2007). Yuen et al. (2006) contend that high-density, high-rise living has increasingly become an embraced, economically viable, and, in certain cases, even preferred mode of habitation in cities such as Hong Kong, Tokyo, and Singapore, which face distinct challenges like urban growth, land scarcity, and housing shortfalls. Nevertheless, Chatterjee's (2009) recent investigations emphasise that, when given a choice and adequate financial means, the majority of people would elect to reside in less densely populated suburban areas.

A paramount challenge for contemporary urban designers lies in crafting sustainable, functional urban spaces capable of addressing the diverse, intense, hybrid, and dynamic urban conditions and pandemics of the present day (Cho et al., 2015; Cho, 2019; Sharifi & Khavarian-Garmsir, 2020). This endeavour requires a reconceptualisation of prevailing notions of density, space, typology, and publicness in high-density, high-intensity urban environments, encompassing not only quantitative factors but also qualitative dimensions. Urban design solutions ought to accommodate the social and economic aspects of sustainability, providing ample social spaces, community facilities, and infrastructure, including public transportation, to bolster liveability and wellbeing for residents (Andres et al., 2021; Sartorio et al., 2021).

Furthermore, sustainable urban design solutions must take into account the environmental and economic consequences of urbanisation, striving to establish cities that maintain both environmental and social sustainability (Andreucci et al., 2022; Carmona, 2019; Carmona et al., 2010). Urban planners must acknowledge that the process of crafting sustainable urban spaces entails social, economic, and political considerations, all of which warrant attention in order to attain sustainable and equitable urban spaces (Corburn, 2017; Barton & Grant, 2013).

3.1.1 Hyper-Density and Its Implications for Sustainable Living

Addressing the challenge of managing urban population growth in a sustainable and equitable manner constitutes one of the most pressing issues of the twenty-first century. Architects, developers, and urban planners are tasked with determining the most appropriate urban form to accommodate future populations while considering the welfare of both the planet and its inhabitants. Over the past two centuries, the proposed solutions have ranged from rural areas and suburban settings to urban centres (Oldfield, 2019; Batty, 2018).

The compact city model is widely acknowledged as a more sustainable alternative to dispersed suburban areas; however, the use of tall buildings remains a subject of debate. Detractors contend that constructing tall edifices does not necessarily result in high-density, sustainable urban forms (Oldfield, 2019; Jenks et al., 1996). Lionel March's interdisciplinary research, merging mathematics and architecture, elucidated that density is not inherently synonymous with height. In his seminal work, "Urban Space and Structures", March demonstrated that a mid-rise perimeter courtyard block with an expansive open centre situated on a large site can achieve a density equivalent to that of a towering structure surrounded by low and mid-rise buildings (March & Martin, 1972). This revelation suggests the existence of alternative approaches to devising sustainable urban forms that do not rely on tall buildings (Lehmann, 2016; Sharifi, 2019). Consequently, architects, developers, and urban planners must persist in their pursuit of innovative design solutions that emphasise sustainability and the wellbeing of residents.

The misconception that tall buildings are indispensable for high-density urban settings is a prevalent yet mistaken belief. The construction of tall buildings may not necessarily result in high-density urban forms (Churchman, 1999; Morato, 2022). Oldfield (2019) highlights that mid-rise built forms can be as effective as high-rise buildings in achieving compact and sustainable urban environments. However, it is crucial to recognise the significant role tall buildings continue to play in creating high-density urban forms. Oldfield (2019) contends that compact, sustainable cities can be achieved with mid-rise built forms without the skyscraper, but it would be unwise to dismiss the skyscraper's potential contribution to compact urban forms. The tall building has a considerable role in fostering high densities. As a result, architects and urban planners must thoughtfully weigh the relative merits and drawbacks of diverse built forms, including mid-rise and high-rise structures, when crafting sustainable urban environments to accomplish sustainability and liveability objectives (Bibri, 2020; Cho et al., 2015). This necessitates a thorough assessment of various urban design strategies and their corresponding outcomes, alongside an understanding of the broader social, economic, and environmental repercussions of urbanisation.

While mid and low-rise structures can effectively deliver high densities, tall building developments possess the capacity to achieve significantly higher densities exceeding 350 units per hectare, a classification referred to as 'hyper-densities' (Roaf, 2009; Lehmann, 2016;

Oldfield, 2019). Nevertheless, the sustainability and desirability of such hyper-densities for cities remain subjects of ongoing debate. Tall buildings have the potential to facilitate high densities whilst concurrently offering expansive open social and public spaces, which, when judiciously planned, can bestow unique benefits upon the city (Raji et al., 2015; Pomeroy, 2013).

However, devising tall buildings that address user requirements for privacy, community, and suitable spaces for social interaction presents a formidable challenge. Aspects including the architectural arrangement, the availability of open, communal, and individual areas, as well as the accessibility of community amenities collectively shape the user experience (Yuen & Yeh, 2011; Hadi et al., 2018). Consequently, architects and urban planners must rigorously assess the merits and drawbacks of various built forms, including tall buildings, to ensure that their designs foster sustainable, equitable, and liveable urban environments that cater to inhabitants' needs. This necessitates a comprehensive comprehension of the intricate social, economic, and environmental ramifications of hyper-densities and an awareness of the potential consequences of implementing such densities in urban design (Oldfield, 2019; Lin, 2018; Lehmann, 2016).

Hong Kong is a notable example of a city that has fully embraced tall buildings, with a greater number of towers than any other city worldwide. Since the 1840s, most of the mountain island's usable building land has been created by land reclamation, pushing the perimeter out into the original anchorage. The city's distinct geography, characterized by challenging topography and limited land, renders building outwards impractical, thus necessitating building upwards (Lehmann, 2016; Ng, 2017). This strategy has resulted in hyper-densities that have engendered an extremely compact urban form, with the city now boasting some of the world's highest densities. The success of Hong Kong's public transit system is a testament to its hyper-density. The Mass Transit Railway (MTR) is not just a prestigious ornament for the pride of the city (Al-Kodmany et al., 2022). The 221km of line and 159 stations are heavily used by the people. A significant 90% of the city's travels occur via public transport, and half of its inhabitants live within a 500-metre vicinity of a mass rapid transit station (Shelton et al., 2013).

Within the prevailing discourse on urban density, a significant challenge lies in the absence of a nuanced intermediary perspective. The conversation frequently gravitates towards a polarising dichotomy between mid-rise and high-rise developments, seemingly presenting these two alternatives as the exclusive means of addressing the accommodation of burgeoning urban populations (Oldfield, 2019; Lehmann, 2016; Bibri, 2020). This binary is exemplified by the contrasting cases of the Barcelona and Shanghai models, which epitomise the mid-rise and point tower typologies, respectively, and are habitually portrayed as the sole viable options (Oldfield, 2019; Fan et al., 2017). Nonetheless, in reality, there exists no definitive, universally applicable method for attaining compact and sustainable urban density. On the contrary, cities can derive benefits from a diverse array of typologies and densities, each moulded by their distinctive local context, historical background, cultural fabric, and connectivity (Dong et al., 2019; Bibri, 2020; Bay & Lehmann, 2017). Vibrant urban centres typically exhibit a heterogeneous amalgamation of building types, encompassing varying densities and typologies, thereby reflecting the intricate requirements and predilections of their inhabitants (Oldfield, 2019; Bibri & Krogstie, 2017).

In high-density urban environments and tall building developments, the incorporation of elevated social and public spaces, such as sky courts, sky gardens, elevated parks, and rooftop terraces, can contribute to the mitigation of perceived densities (Li et al., 2022; Cho et al., 2015). By including these spaces, designers can evoke a human scale and proportionality reminiscent of traditional streets within urban landscapes. These areas may manifest as either open or enclosed spaces that harmonise the mass of the structure and potentially invigorate the building's form through an interplay of solid (private) and void (semi-public) spaces (Pomeroy, 2012; Yeang, 2007).

Additionally, the integration of elevated social and public spaces within tall edifices facilitates enhanced natural light and ventilation penetration, thereby improving the internal environment (Raji et al., 2015; Al-Kodmany, 2018). Existing research underscores that the merits of these spaces extend beyond their functional attributes to encompass environmental, social, and economic advantages (Samant, 2019; Hadi et al., 2018; Cho et al., 2015; Viñoly et al, 2015). Figures 3.9 to 3.13 exemplify instances of elevated social and public spaces in high-density urban settings and tall structures. Integrating such spaces into the design of tall buildings and high-density developments fosters the creation of more sustainable and habitable urban environments (Pomeroy, 2013; Oldfield, 2019).


Figure 3.9 Mountain Dwelling, Denmark. Source: JDS Architects


Figure 3.10 VIA 57 West, New York. Source: archdaily.com


Figure 3.11 Copen hill urban mountain, Denmark. Source: theguardian.com


Figure 3.12 Denmark Orca is a mixed-use development, Toronto designed by Safdie Architects. Image source:deezen.com


Figure 3.13 Shenye TaiRan Building, located in Shenzhen, China. Image source: skyscrapercenter.com

3.1.2 Hybrid Urban Spaces

The accelerated urbanisation process, coupled with population increase, intensification of urban structures, migration, and cultural heterogeneity, has contributed to the emergence of diverse hybrid spatial typologies (Cho et al., 2015; Ravindranath & Menon, 2018). While the enduring importance of traditional public spaces and their historical forms must not be overlooked, it is imperative to investigate novel strategies for upholding and sustaining public values and identifying contemporary forms of publicness in high-density urban environments (Li et al., 2022; Xue et al., 2017). This methodology is vital for cultivating a lively and dynamic urban landscape. Consequently, a reassessment of conventional notions of public spaces and their capacity to adapt to the ever-changing requirements of city inhabitants is warranted (Cho et al., 2015; Banai, 2020).

Hybrid urban spaces encompass areas that, despite not being publicly owned or governed, are increasingly utilised as communal locations (Carmona, 2019; Ali & Al-Kodmany, 2012; Holl, 2014). These spaces display unique typologies, attributes, and regulatory systems compared to traditional public spaces, such as public squares and parks (Childs, 2006; Ali & Al-Kodmany, 2012). Emerging innovative hybrid urban spaces consist of elevated areas and multi-storey structures (for instance, pedestrian bridges, rooftop gardens, sky courts, and sky parks) and intensified mixed-use residential establishments. Included within these spaces are extant buildings and infrastructure that undergo adaptation and repurposing to function as civic locales. Childs (2006) refers to such spaces as "unsung civic places." The recognition, examination, and suitable management of these hybrid urban spaces are essential for fostering lively and sustainable urban settings.

In the development of hybrid urban spaces, several fundamental principles support the establishment of dynamic and harmonious environments that seamlessly integrate with a city's infrastructure (Cho et al., 2015; Krasilnikova & Klimov, 2016). These guiding principles encompass prioritising high-quality design and functionality, presenting an assortment of programme options catering to a wide range of user requirements, affording opportunities for both fixed and adaptable activities, and ensuring safety and accessibility (Holl, 2014; Oldfield, 2019). Accomplishing successful hybridisation necessitates heightened interaction between structural and programmatic components, resulting in the mutual intensification and activation of the adjoining context. The primary objective of generating hybrid spaces is to minimise transportation needs and augment the local environment by incorporating green spaces that foster sustainability and habitability (Lehmann, 2016; Churchman, 1999; Pomeroy, 2013).

In high-density urban contexts, hybrid spaces embody dynamic and frequently divergent systems that interweave spatial configurations, programs, utilization practices, and management strategies, driven by competing and intense tensions among diverse user groups and governing agencies (Tian & Jim, 2011; Carmona, 2010; Iveson, 2013). The development of hybrid spaces has given rise to three intersecting modes of hybridization: spatial, programmatic, and operational (ownership) hybrids, reflecting the complex and multifaceted nature of hybrid spaces (Cho et al., 2015; Di Marino et al., 2022). These modes capture the intricate interplay between the physical and social dimensions of hybrid spaces

(Carmona, 2010; Madanipour, 2019), as well as the interdependent relationships between the various actors and stakeholders involved in their creation and management (Iveson, 2013; Low, 2006).

The spatial hybridisation of urban space entails complex structural arrangements and technological advancements that interact with the surrounding context to generate new spatial conditions conducive to enhanced access, connectivity, physical flexibility and innovative public uses (Frantzeskaki et al., 2017; Cho et al., 2015). Such a transformation challenges the traditional layout-centric approach and underscores the significance of three-dimensional modelling and sections. The development of hybrid urban spaces has given rise to novel design manifestations such as elevated public spaces, multilevel public spaces, and underground public spaces, all of which reflect the dynamic and multifaceted nature of hybridisation (Rossini & Yiu, 2021; Cho, 2019; Wood, & Safarik, 2019).

The concept of 'programmatic hybrids' refers to the combination of various activities that are mutually complementary and conducive to unconventional uses of space (Cho et al., 2015, 2017; Iveson, 2013). Examples of functional hybridization include cases whereby railway stations and other transportation infrastructures are combined with shopping, offices, hotels, and apartments within the same development (Champagne et al., 2022; Ellin, 2013; Edwards, 2011). This notion goes back more than a hundred years, with celebrated examples like St Pancras, London, Lime St, Liverpool, and Grand Central, New York. A contemporary example is the Westfield Stratford City, combining Crossrail, Eurostar, Network Rail, and the London Olympic Park (Gold & Gold, 2010), or Hudson Yards in New York, at Penn Station (Mattern, 2016).

Flexible and multifunctional design and programming are among the methods promoted by the latest large-scale developments to optimize space utilization and cater to a range of groups (Cho et al., 2015). This approach to hybridization focuses on integrating diverse functions, activities, and green spaces within the same curtilage, resulting in novel and innovative modes of space usage that better serve the needs of urban residents (Iveson, 2013; Oldfield, 2019).

The operational hybrid framework, recently developed for spatial negotiation, aims to transform access, territoriality, and conventional boundaries by incorporating negotiated ownership, safety optimization, space utilization, management, and scheduling (Cho et al., 2017; Lehmann, 2016). In the context of urban development employing this operational hybrid approach, contractual relationships, such as public-private partnerships, play a pivotal role in moulding regulatory frameworks and governance practices (De Magalhaes, 2010; Cheng et al., 2021). These partnerships are instrumental in shaping the public domain, fostering interaction and collaboration among diverse stakeholders, and ensuring that hybrid spaces achieve their maximum potential. Additionally, they promote safety and accessibility for all users (Caperchione et al., 2017; Cho et al., 2015).

Hybrid buildings are characterized by a high degree of programmatic complexity and encompass both the architecture and the urban context (Pomeroy, 2013; Abdelsalam, 2018; Oldfield, 2019). They are seen as an improved version of mixed-use buildings, designed to address challenges such as land scarcity (Holl, 2014; Ali & Al-Kodmany, 2012; Mayekar, 2017). While mixed-use buildings are intended to integrate various programs into a single building, the distinctive feature of hybrid buildings lies in their optimal arrangement of internal space and the interaction between users (Salami et al., 2021) (Figure 3.13). In contrast to the functional demands of mixed-use buildings, today's hybrid buildings are intended to be designed as interesting interior spaces that are connected to their context. As Holl has noted, "hybrids are incomplete and necessarily rely on the organization of the whole in a way that reorganizes the social dimension of the building" (Holl, 2014: 23).

Hybrid buildings are a thoughtfully crafted and designed structure that integrates shared common spaces and highly connected areas to create a cohesive building that operates as a unified whole (Al-Kodmany, 2018; Cho et al., 2015). The various components of the hybrid building interact with and depend on each other, resulting in a highly interconnected relationship between the different uses and programs (see Figures 3.14, 3.15, and 3.16). The extensive level of integration among different programs and uses in hybrid buildings is the result of careful planning and design, with an emphasis on the creation of a space that is both unified and conducive to user interaction with each other and the surrounding environment (Lehmann, 2016; Oldfield, 2019; Al-Kodmany, 2022). Hybrid buildings are not simply functional spaces that satisfy the basic requirements of their users but rather, they encourage social interaction and foster a sense of community (Cho et al., 2015; Hadi et al., 2018). Thus, hybrid buildings represent a promising and innovative approach to urban development that addresses the complex demands of contemporary society (Figure 3.17, 3.18, and 3.19).

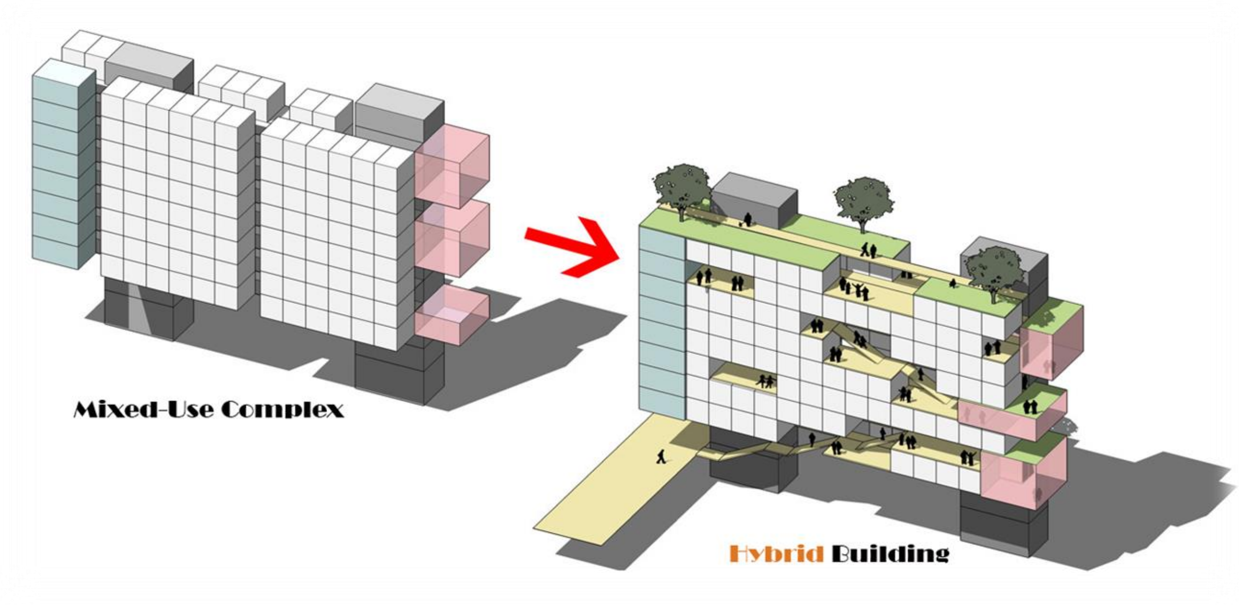


Figure 3.14 Hybrid Building concept, Source: archdaily.com

Figure 3.15 Hybrid Building concept. Source: Author

Figure 3.16 Conceptual section of the hybrid buildings concept. Source: Author

Figure 3.17 Expo 2000, Netherland pavilion, Source: MVRDV.

Figure 3.18 park royal Singapore source: CTBUH Journal Source Panoramio, available at: http://www.panoramio.com/photo/332152079

Figure 3.19 Elbphilharmonie Hamburg / Herzog & de Meuron, source: Iwan Baan, Maxim Schulz, edited by the Author.

3.2 The History of Elevated Social Spaces and Vertical Public Realm

Elevated green social spaces, a novel typology of public spaces, are characterised by their elevation above the surrounding ground plane and private ownership and management (Hadi et al., 2018; Pomeroy, 2013; Osmundson, 1999). Distinct from traditional public open spaces, such as city squares and parks, these hybrid spaces possess unique attributes and regulatory frameworks (Oldfield, 2019; Cho et al., 2015). The urban landscape has witnessed the emergence of diverse hybrid spatial forms, including elevated and multi-level spaces, which incorporate natural elements. Contemporary urban environments feature pedestrian bridges, shopping malls, and transport interchanges integrated with green spaces, leading to the development of sky courts, sky gardens, and sky parks (Samant, 2019; Viñoly et al., 2015).

The emergence of the tall building typology within urban environments since the 1880s has primarily been an economic response to the demand for centralising workers on valuable city centre land, in proximity to high-quality metropolitan transport, and with the intent of generating profit from development (Parker & Wood, 2013; Oldfield, 2019). However, the tall building typology has frequently been associated with exacerbating psychological and social issues due to the lack of active open spaces, which are vital in providing ventilation, natural light, and opportunities for social interaction (Pomeroy, 2013; Kalantari & Shepley, 2021).

In recognition of these concerns, the New York Zoning Law of 1916, along with numerous subsequent updates, constituted a concerted effort by the city to ensure developers prioritise public health by facilitating access to light and air at street level (Sze, 2006; Fischler, 1998). This precedent has been replicated and reinterpreted globally, continuing to apply in New York and echoed in countless urban centres such as Toronto, Brisbane, and Singapore through various tall building design guides (Oldfield et al., 2009; Al-Kodmany, 2018; Schröpfer et al., 2019). Despite the evident significance of public spaces in fostering well-being, health, productivity, and social connections, many developers have neglected these aspects in their designs, often due to economic considerations (Triguero Mas et al., 2020; Lee & Park, 2018). This oversight in addressing the crucial role of public spaces in urban environments underscores the necessity for a more comprehensive understanding of the relationship between the built environment and human well-being.

The historical precedents of tall structures, elevated social spaces, and sky gardens are well established, dating back to ancient civilizations. For instance, the Babylonian garden, documented by Greek historian Diodorus Siculus in the 6th century BCE, represents a seminal instance of this typology (Figure 3.20). It comprised a series of planted terraces supported by stone arches, elevated 23 metres above the ground (Dalley, 1994). Another notable example is Al-Fustat, an ancient Egyptian city now known as Old Cairo, which was renowned for its street gardens and vertical open markets called El-Wekalla. These markets similarly incorporated sky gardens (Mason, 1995). These historical examples underscore the long-standing and deeply rooted nature of the concept of vertical social spaces and sky gardens, indicating that it is not a recent phenomenon.

By the late 19th century, the Eiffel Tower in Paris had emerged as a seminal example of the commodification of panoramic views, drawing visitors from around the world who paid a fee to admire the Parisian skyline (Barthes, 2012). This model was extensively adopted by other tall structures worldwide, aiming to provide similar observation galleries and capitalize on the allure of picturesque vistas (Figure 3.21). Notably, the Empire State Building in New York, completed in 1931 and famous for being the tallest building in the world at the time, generated its initial income from panoramic tourism long before its office spaces were fully occupied by tenants (Kingwell, 2006; Willis, 1992).

Figure 3.20 Hanging Gardens, Source: Christopher Klein

Figure 3.21 Eiffel Tower Platform, Paris. Source: Viacheslav Lopatin

In the 20th century, the influential architect Le Corbusier significantly developed this concept in his manifesto, which highlighted the rooftop as a crucial element of architectural design (Cohen, 2004; Oldfield, 2019). By elevating the building above ground level, he provided opportunities for open recreation and improved light and ventilation (Figure 3.23 and 3.24). This idea was apparent in his designs for Villa Savoye and Unité d'Habitation, which incorporated rooftop gardens and other green spaces (Sbriglio, 2004; Ali & Al-Kodmany, 2012). Even today, visitors can enjoy a walk on the roof of the Unité without any payment or reservation.

The concept of creating streets and communal spaces in the sky boasts a long and rich history. Within three decades following the construction of Chicago's Home Insurance Building, the first 'skyscraper' completed in 1884, future city visions featuring elevated playgrounds, parks, and towers connected by sky-bridges were being imagined (Figure 3.22) (Wood, 2003; Oldfield, 2019). Such concepts originated from escalating ground-level congestion and the increasing influence of automobiles, with the objective of lifting the urban dwellers' experiences above the hustle of the traffic underneath (Figure 3.25) (Bansal et al., 2017).

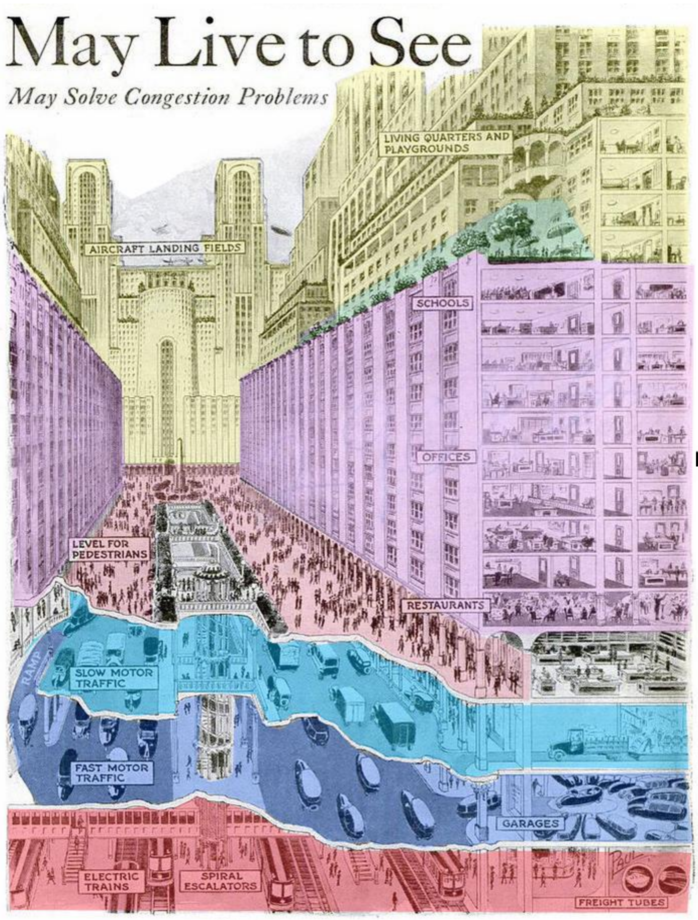


Figure 3.22. The wonder city you may live to see: a vision of the city of 1950 by Harvey M. Corbett, Edited by the Author

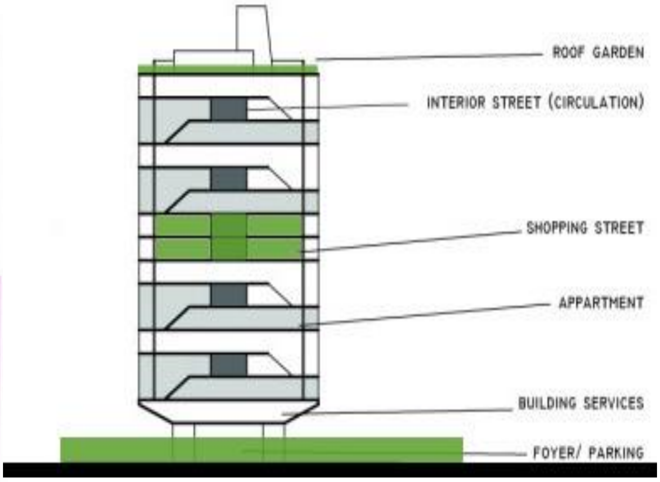


Figure 3.23: Unite d'Habitation diagrammatic section of communal Spaces. Source: Philip Oldfield

Figure 3.24: Unite d'Habitation, Marseille. Source: Michael 1972

Figure 3.25. Conceptual visions of creating streets in the sky inspired by Harvey M. Corbett. Source: Author

These early visions of urban life in the sky signify a burgeoning awareness of the importance of creating liveable and sustainable urban environments. They also demonstrate the enduring interest in the potential of vertical social spaces to shape the future of our cities.

One of the earliest and most influential examples of integrating vertical social spaces into tall buildings can be found in Le Corbusier's Unité d'Habitation in Marseille, constructed between 1948 and 1952 (Sbriglio, 2004; Boesiger & Girsberger, 2000). Le Corbusier conceived the building as a prototype for the Ville Radieuse ('Radiant City'), a master plan for a vertical garden city incorporating a diverse array of communal spaces and services within its design (Oldfield, 2019; Millais, 2015). The Unité's social facilities were distributed across three distinct public levels: an open ground level space with the main mass of the building elevated on columns; a public street situated on levels seven and eight, encompassing a hotel, restaurants, bars, laundry facilities, and shops; and a public roof terrace, accommodating a gymnasium, swimming pool, and nursery (Jenkins, 1993; Millais, 2015). This case study exemplifies the early integration of vertical social spaces into tall building design, showcasing a visionary approach to creating multi-functional and interconnected environments within a single structure.

Le Corbusier's Unite d'Habitation is a seminal example in the history of vertical social spaces, demonstrating how these spaces can be effectively integrated into tall building design (Corbusier, 2013; Woudstra, 2000). It continues to influence architects, urban planners, and designers, and is widely regarded as a pioneering instance of the integration of vertical social spaces into tall buildings. The building serves as a testament to the potential of these spaces to enhance the livability and sustainability of urban environments.

While Le Corbusier's vision of incorporating communal spaces and services into vertical buildings was groundbreaking, its implementation in the Unité d'Habitation in Marseille has only achieved partial success. The shopping street, originally intended to function as a bustling public space, was relegated to a small bakery and supermarket primarily utilized by residents, largely due to its concealed location within the block (Oldfield, 2019; Woudstra, 2000). Consequently, the remaining shop spaces were repurposed as 'boutique offices'. Furthermore, the central corridor design of the building's residential floors lacked access to natural daylight, resulting in a dim and uninviting interaction space, although the office and hotel floors feature a side corridor with daylight (Millais, 2015; Toland, 2001). These limitations and challenges underscore the complexities associated with fully realizing the potential of vertical social spaces in vertical buildings, and emphasize the crucial role of meticulous design, location, and functionality considerations in their development.

Expanding upon these historical precedents, architect Ken Yeang advanced the concept of vertical social spaces by incorporating them as a central and active component within tall buildings (Figure 3.26) (Yeang, 2002). Yeang recognised their significance not only for social reasons but also for their potential environmental benefits (Yeang & Richards, 2007; Yeang, 2008). As a prolific author of books and articles on the subject of green or 'bioclimatic skyscrapers', Yeang has significantly influenced and inspired an entire generation of architects and students. These developments underscore the evolution of vertical social spaces and sky gardens, illustrating their integration into contemporary architectural design and urban planning (Yeang, & Powell, 2007; Pomeroy, 2013).

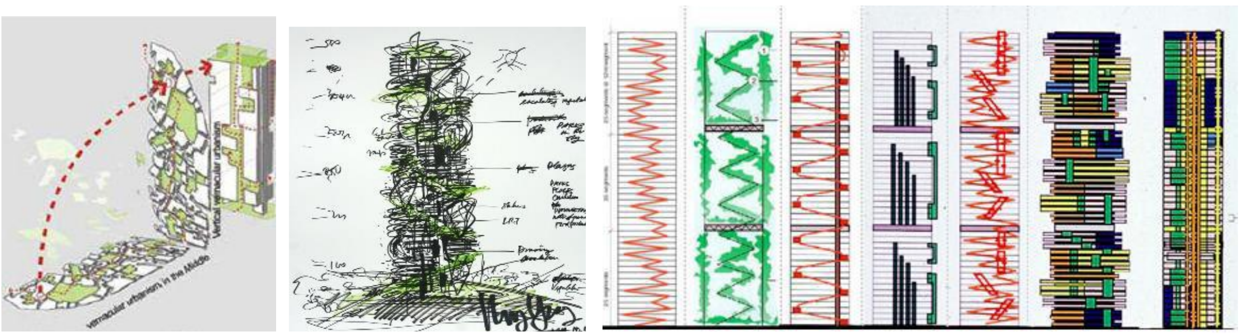


Figure 3.26: Ken Yeang Sketches, Source: Reinventing the Skyscraper: a Vertical Theory of Urban Design

Despite the historical significance of vertical social spaces, their successful implementation in tall buildings has proven to be a challenge (Oldfield, 2019; Hadi et al., 2018). The lack of active open spaces in urban environments exacerbates psychological and social issues, underlining the necessity for a comprehensive understanding of the relationship between the built environment and human well-being (Li et al., 2022; Yuen & Hien, 2005). Although Le Corbusier's Unite d'Habitation serves as a pioneering example, it has only partially succeeded in realising the full potential of vertical social spaces. The encountered limitations and challenges in the creation of such spaces emphasise the importance of meticulous consideration of design, location, and functionality for their successful integration (Cho et al., 2015).

In conclusion, the incorporation of elevated social spaces and sky gardens in tall building design boasts a long and rich history, originating in ancient civilisations and persisting as an influential factor in contemporary urban planning. The concept of crafting liveable and sustainable urban environments through the integration of these spaces is well established. However, the creation of successful and functional vertical social spaces has remained a challenge, both in the past and now in the 21st century.

3.2.1 Elevating Nature: Singapore's Endeavour in Creating Green Streets in the Sky

The notion of establishing vertical communal and social spaces within tall buildings has recently gained renewed interest in Singapore (Oldfield, 2019; Hadi et al., 2018). As a highly dense and culturally diverse country with residents from various ethnic backgrounds, Singapore, like many other Asian cities, is experiencing a significant surge in the construction of tall buildings, resulting in a greater concentration of life in the vertical realm (Li & Du, 2022; Newman, 2014). Singapore provides several precedents for tall buildings that promote the development of socially sustainable vertical communities (Figure 3.27). The city has successfully transformed conventional repetitive high-rise housing blocks into innovative and ambitious urban hybrid spaces and communal areas that cater to the needs of both residents and the wider public (Samant, 2019; Pomeroy, 2013). This phenomenon reflects the evolving urban landscape and the importance of integrating social sustainability into the planning and design of tall buildings, particularly in Singapore, where the population's high density necessitates innovative solutions to meet the residents' social and communal needs (Li et al., 2022; Yuen, & Hien, 2005).

In numerous countries, public housing is frequently associated with substandard quality and high crime rates. However, this is not the case in Singapore. The government-provided residential apartments in Singapore are well-maintained, clean, and considered secure (Yuen & Hien, 2005). This can be attributed, in part, to the fact that a significant proportion of the population, approximately 80% as reported by the Singapore Housing and Development Board (HDB), resides in public housing (Li et al., 2022). Moreover, Singapore distinguishes itself as one of the few countries worldwide to have achieved a high rate of homeownership, with over 90% of households owning their homes (Phang & Helble, 2016). These statistics underscore the unique character of public housing in Singapore and the success of the Housing and Development Board in providing high-quality, affordable living spaces for its residents.

During the mid-twentieth century, Singapore faced a pressing housing crisis as it struggled to accommodate its rapidly growing population (Newman, 2014). In response, the city's first Prime Minister, Lee Kuan Yew, established the Housing and Development Board (HDB) in 1960 (Oldfield, 2019). The HDB was mandated to construct rental units for low-income individuals and families, many of whom were living in unsanitary slums and informal settlements. Through its efforts, the HDB successfully relocated these individuals to new high-rise developments, thereby improving the standard of living for many immigrants, including those from Malaysia (Oldfield, 2019).

In its early stages, the primary objective of the Housing and Development Board (HDB) in Singapore was to address the pressing housing crisis and build a substantial number of rental units in a timely manner (Oldfield, 2019). However, as time progressed, the HDB shifted its focus to the creation of thriving communities (Samant & Hsi-En, 2017). This was achieved through a two-pronged approach. Firstly, progressive design tactics were executed to embed social communal spaces within varying vertical dimensions - the base, mid-section, and apex of the residential towers (Pomeroy, 2012). Subsequently, the fostering of community involvement and the assimilation of residents within emergent high-rise establishments were purposefully pursued and systematically orchestrated (Hadi et al., 2018).

The Housing and Development Board (HDB) of Singapore incorporated "void decks" into many of its projects as a means of providing ample communal spaces at the ground level (Pomeroy, 2013). However, as taller towers were needed to accommodate the country's dense population, HDB recognized that residents living on upper floors would become disconnected from the bustling activities on the ground (Samant, 2019). This led to the resurgence of sky gardens and high-rise communal spaces, often in the form of lush gardens, to address this issue (Pomeroy, 2012). The popularity of sky gardens has since surpassed that of the void deck, becoming a defining communal space in high-rise buildings in Singapore (Li & Du, 2022).

Singapore's public housing system is unique in that it is not restricted to only serving low-income families (Li et al., 2022). The Housing and Development Board (HDB) provides flats that are typically 20-30% less expensive than those in the private market (HDB, 2016). This affordable housing option has been instrumental in promoting social integration and preventing ethnic and economic polarization (Yuen & Hien, 2005). The government recognizes the importance of creating a diverse community across all neighbourhoods and has made efforts to build new high-rise housing developments that cater to a mix of people from different socio-economic backgrounds (Oldfield, 2019).

The policy of integrating different classes of people in the same neighbourhood has been successful in reducing poverty and creating a more harmonious society (Newman, 2014). According to the Prime Minister of Singapore, Tharman Shanmugaratnam, this policy has ensured that while there may still be families in poverty, there are no longer any poor neighbourhoods in the country (Phang & Helble, 2016). The HDB's public housing policy has therefore been a crucial factor in achieving the government's goal of creating a fair and inclusive society.

The government's efforts to provide affordable housing to all citizens, regardless of their income level, have been lauded by many (Yuen & Hien, 2005). The HDB's public housing policy has helped to ensure that Singapore remains one of the most livable cities in the world (Newman, 2014). Despite being a small city-state, Singapore has a high standard of living, a well-developed infrastructure, and a thriving economy (Li et al., 2022). These factors, combined with the government's commitment to promoting social integration, have contributed to Singapore's success as a nation (Oldfield, 2019).

The advancement of sky gardens has been championed by the Housing and Development Board (HDB) in the context of social high-rise habitation, while private enterprises are spurred to integrate such domains through the enactment of the Landscaping for Urban Spaces and High-rises (LUSH) planning directive (Li et al., 2022). This regulatory approach is propelled by Singapore's strategic ambition to craft a 'Garden City' (Newman, 2014). The LUSH policy mandates that property developers incorporate green spaces - situated either at ground level or elevated positions - that span at least the aggregate area of the site (Huang et al., 2019; Oldfield, 2019; URA, 2014). Additionally, developers who incorporate sky gardens, landscaped rooftops, and alfresco leisure zones can avail themselves of exclusions from floor area tax and enhanced plot ratios, thereby enabling them to construct beyond the parameters defined by local zoning regulations (Timm et al., 2018).

Consequently, the progressive urban planning policies and regulatory frameworks initiated by the Singaporean government have given rise to a proliferation of high-rise structures featuring prominent sky gardens and substantial spaces dedicated to horizontal and vertical verdure (Li & Du, 2022). These increasingly popular vertical green communal areas contribute not only to a distinctive visual appeal and fostering community interactions (Hadi et al., 2018), but also function to provide shade and counteract the urban heat island phenomenon (Pomeroy, 2013). Essentially, the wide-spread implementation of sky gardens in Singapore is not a serendipitous occurrence, but a calculated outcome of strategic urban planning and regulatory mechanisms.

The Landscaping of Urban Spaces and High-rises (LUSH) planning circular has been a pivotal factor in the promotion of sky gardens and green spaces within the urban fabric of Singapore (Li et al., 2022). The implementation of this policy has not only augmented the visual appeal of the city, but has also brought about environmental and social benefits (Li & Du, 2022; Siong et al.,2013; Wong et al., 2010). The green spaces serve to mitigate the negative effects of the urban heat island phenomenon, reduce air pollution levels, and provide communal spaces for residents to engage in leisure activities and foster social interaction (Yuen & Hien, 2005). Furthermore, the LUSH policy advances sustainable urban development through the reduction of the city's carbon footprint and energy consumption through the mitigation of thermal loads (Oldfield, 2019). In conclusion, the success of the LUSH policy serves as a benchmark for other cities seeking to promote sustainable urban development and improve the quality of life for their inhabitants (Li et al., 2022).

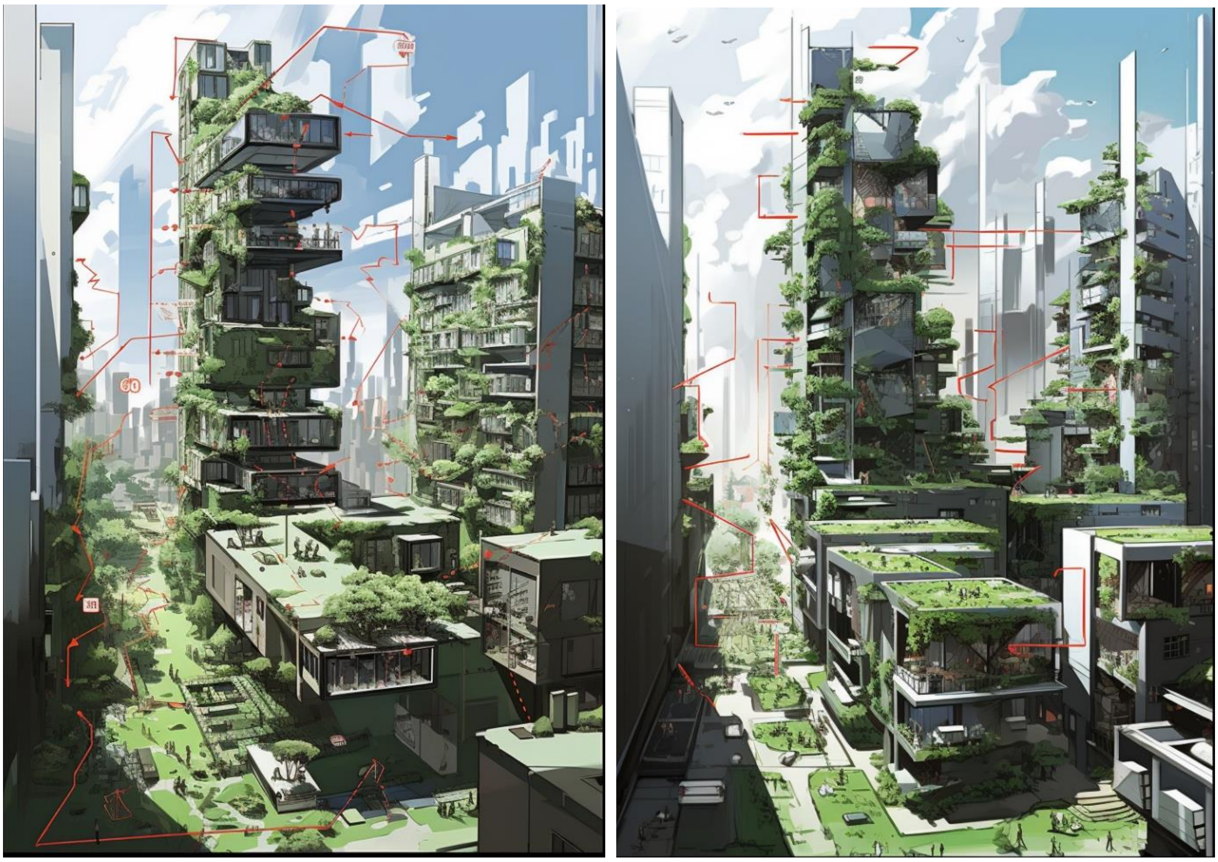


Figure 3.27 Conceptual Sketches for Singapore Approach in Rethinking Tall Buildings , Source: Author

3.2.2 An overview of Singapore’s skyrise greenery projects (innovative design strategies for building vertical communities)

The integration of sky gardens into high-rise buildings in Singapore was first exemplified by the 'Pinnacle@Duxton' development, designed by ARC Studio Architecture and Urbanism. Comprised of seven interconnected towers, the project accommodates a substantial number of residents (Figure 3.27 and 3.34). What sets the Pinnacle apart from other developments is its two dramatically designed sky gardens, located on levels fifty and twenty-six, which connect all seven towers together (Hadi et al., 2018). The sky garden, positioned at the pinnacle of the development at a height of 150 metres, functions as a publicly accessible hybrid garden, while the 26th-floor sky garden is dedicated exclusively for residents. This sky garden design presents a marked departure from traditional "streets in the sky" concepts from previous decades (Oldfield, 2019). Significantly, vegetation is not only recognised but also integrated as a crucial component of the architectural fabric, instead of being relegated in the face of concrete-dominant design strategies. Secondly, the sky gardens offer a diverse range of functions, including an outdoor gym, a children's playground, a running track, and a community meeting space for residents (Samant & Hsi-En, 2017; Hadi et al., 2018).

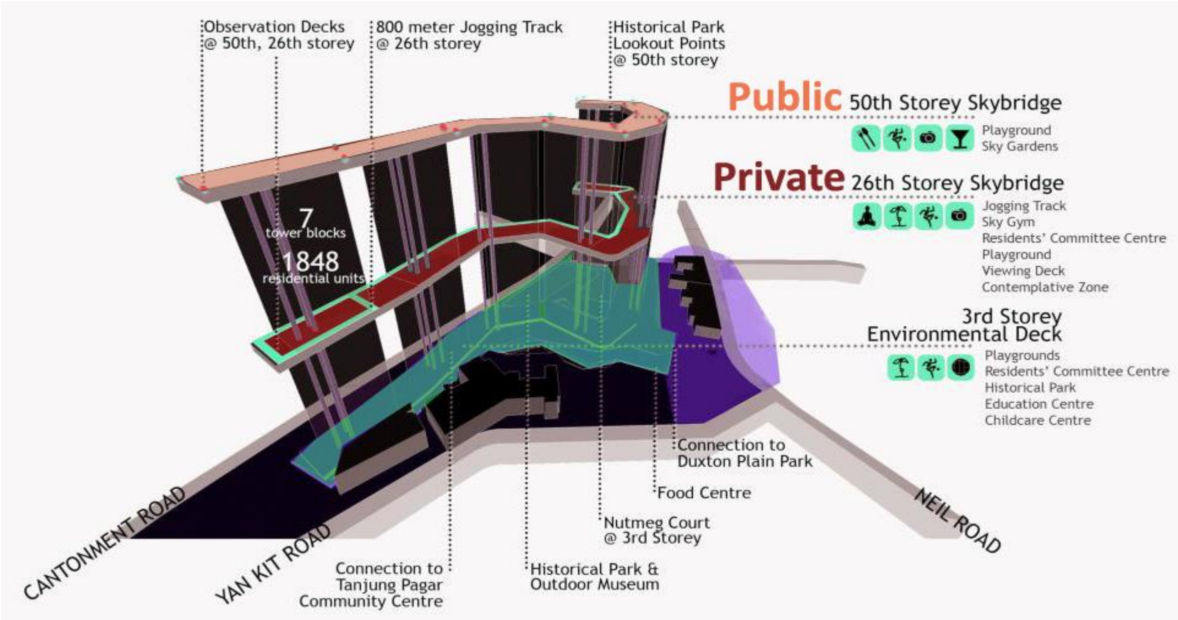


Figure 3.27: The Pinnacle@Duxton Skygardens Diagram, Source: Author

The Interlace building, designed by the Office for Metropolitan Architecture (OMA), represents a departure from the conventional approach of constructing isolated towers and connecting them only at ground level. The innovative design of the building proposes a stacking of horizontal blocks, which creates a dynamic urban topography that acts as a generator of communal spaces for community and social interaction (Bischeri & Micheli, 2016) (Figure 3.28). This unique approach results in the creation of extensive roof gardens and terraces situated across multiple levels, offering a range of scales and views, both sheltered and open. These communal garden spaces are strategically located adjacent to private balconies, providing a balance between visibility and privacy while also contributing to the overall security of the building (Oldfield, 2019; Lehmann, 2016) (Figure 3.28).

The Interlace building exemplifies a new paradigm in architectural design, prioritizing the creation of communal spaces within the built environment (Figure 3.28, 3.33 and 3.35). It demonstrates the potential for vertical developments to promote social cohesion and enhance residents' quality of life (Samant & Menon, 2018). The innovative design of the building is a testament to architects' ability to reimagine conventional approaches to urban development and create spaces that are both functional and aesthetically appealing (Ilgin, 2021). The Interlace building serves as a model for other architects and urban planners, highlighting innovative design solutions' potential to address the challenges posed by dense urban environments (Bischeri & Micheli, 2016).

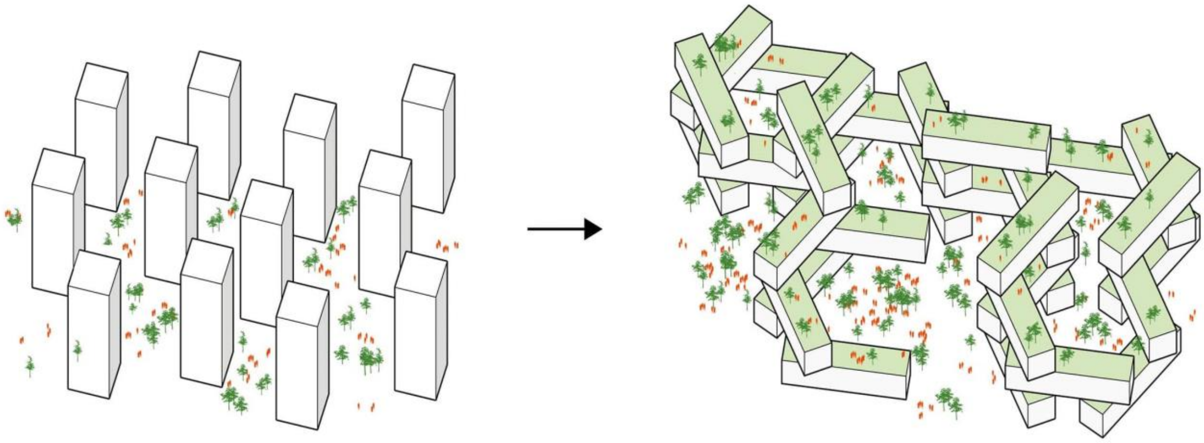


Figure 3.28 The Interlace Singapore, traditional site arrangement versus the stacked horizontal blocks. Source: OMA/Ole Scheeren

The Sky Habitat, designed by Moshe Safdie, is a notable example of a hybrid building that balances high-density living concepts with sustainable vertical urbanism, including community, landscapes, gardens, and daylight (Samant, 2019; Wong et al., 2018). The design of the thirty-eight-story residential complex references traditional hill towns and villages found in regions such as Provence and Italy, as well as the rock-cities of Cappadocia, focusing on creating a comfortable human scale that provides individual identity within the building and its shared external spaces (Lubin, 2016) (Figure 3.29 & 3.30).

The Sky Habitat features three bridging sky gardens that connect two stepping towers, creating a series of interconnected streets and gardens in the air (Lubin, 2016). These communal spaces offer opportunities for recreation and social interaction, while the open and porous overall mass of the building allows for the flow of daylight and breezes (Li & Du, 2022) (Figure 3.29 and 3.32). The stepping geometry of the building provides every residence with multiple orientations and private outdoor spaces (Lubin, 2016; Pomeroy, 2012). This innovative approach to high-rise living demonstrates the potential for sustainable and community-focused design in dense urban environments (Pomeroy, 2013; Oldfield, 2019).

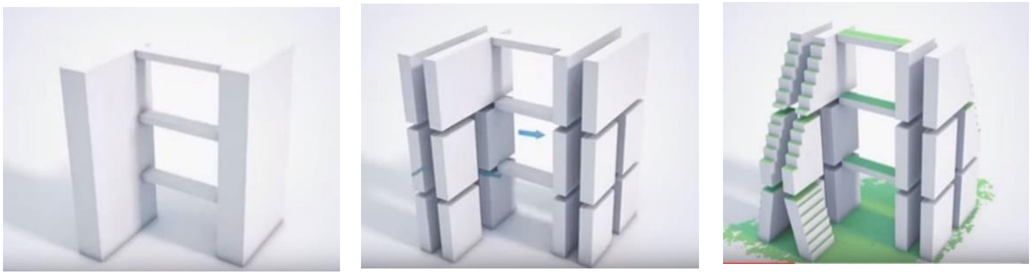


Figure 3.29 Sky Habitat Singapore form development, by: Safdie Architects, edited by: Author

Figure 3.30 Sky Habitat sky gardens, by: Safdie Architects, source: Archdaily, available at: http://www.archdaily.com/781936/sky-habitat-singapore-moshe-safdie

The Oasis Hotel Downtown, designed by WOHA, serves as another outstanding example of incorporating sky gardens in Singapore's high-rise buildings. The project expertly combines hotel, office, and club-room programs into a single tower, addressing the challenge of limited open space on a tight urban site measuring 60 by 60 metres (Wong et al., 2018). In response to this constraint, the design incorporates sky gardens for each program, providing ample communal spaces for the occupants at height (Figure 3.31).

Each sky garden measures approximately 30 by 30 metres, making them equivalent in size to small urban parks (Wong et al., 2018). The dominant aesthetic is driven by the abundant vegetation, encompassing both horizontal sky gardens and vertical green walls. In this manner, the building provides an impressive 1,100% of the original site area as new greenery, establishing a remarkable example of a hybrid private building in an urban context (Wong et al., 2018; Newman, 2014).

This innovative approach to integrating green spaces in high-rise buildings demonstrates the potential for architects and urban planners to address the challenges of limited open space in dense urban environments. By prioritizing the inclusion of communal spaces and greenery, the Oasis Hotel Downtown sets a strong precedent for future developments, emphasizing the importance of sustainable and community-focused design in urban settings (Samant & Menon, 2018; Li et al., 2022).

Figure 3.31 Oasia Hotel Downtown, Singapore. Source: K. Kopter

In conclusion, the concept of sky gardens and communal spaces within tall buildings in Singapore represents a unique and innovative approach to urban development. This approach is driven by the need to accommodate the city's dense population and promote social sustainability, as well as the government's commitment to creating a fair and inclusive society (Newman, 2014). The Housing and Development Board (HDB) has played a crucial role in the promotion of sky gardens in social housing through the Landscaping of Urban Spaces and High-rises (LUSH) planning circular (Yuen & Hien, 2005). This policy has been instrumental in creating a more livable city and promoting sustainable urban development, by reducing the city's carbon footprint, mitigating the urban heat island effect, and providing communal spaces for residents (Samant & Menon, 2018).

The examples discussed in this section highlight the innovative design strategies employed by architects and urban planners to create vertical communities in Singapore. The Pinnacle@Duxton, Interlace, Sky Habitat, and Oasis Hotel downtown serve as models for other cities looking to promote sustainable urban development and improve the quality of life for their inhabitants (Figure 3.34, 3.35, and 3.36) (Li et al., 2022). These projects demonstrate the potential for sky gardens to promote social cohesion and enhance the aesthetic appeal of high-rise buildings (Samant, 2019). Overall, the integration of sky gardens into high-rise buildings in Singapore represents a unique and innovative approach to urban development that is worthy of further study and consideration by other cities around the world (Pomeroy, 2013).

Singapore has fully embraced the concept of vertical urbanism, with the incorporation of sky gardens and vertical social communal spaces becoming a standard feature in new high-rise developments (Pomeroy, 2012). These sky gardens are widely present in both public Housing Development Board (HDB) and private high-rise housing projects in Singapore (Yuen & Hien, 2005; Hadi et al., 2018). The trend of incorporating high-rise design with proposals for residential and public sky gardens is spreading globally, including cities such as London and Los Angeles (Oldfield, 2019). This shift towards incorporating sky gardens into high-rise design represents a positive move away from the monotony of repeated floor plans and bulky building forms. Despite this progress, there remain concerns regarding the level of privacy, safety, bureaucratic overreach, and inclusiveness of these spaces (Oldfield, 2019).

The mere presence of sky gardens in vertical developments does not necessarily guarantee the creation of successful communities or resident satisfaction. Case in point is 'The Pinnacle', where its sky garden is subjected to stringent access regulations. Admittance to the intermediate-level sky garden is confined to card-carrying residents through metal turnstiles, while entry to the uppermost public level is regulated by designated operating hours, visitor limits, and a mandatory entrance fee (Hadi et al., 2018). A prescribed set of rules, posted at the entrance, prohibits the consumption of food and drink, social gatherings, and activities such as cycling and skateboarding. Furthermore, the single-use nature of the key card system curtails residents from inviting guests to the sky garden, as each turnstile grants access to only one individual at a time.

A subsequent post-occupancy assessment of 'The Pinnacle' sky garden disclosed that, notwithstanding the robust security protocols, the garden experienced consistent utilisation by the residents, averaging more than 800 users daily on each level (Hadi et al., 2018).The study found that the sky garden provided a successful escape from the city and a peaceful environment. However, the most common sentiment among residents was frustration with the management of the space, as the strict security measures and usage restrictions limited their enjoyment of the sky garden (Hadi et al., 2018).

In light of these findings, it is essential for urban planners and architects to strike a balance between security concerns and fostering a sense of community in designing sky gardens and communal spaces. It is crucial to consider the needs and preferences of residents while also addressing safety and privacy concerns. By doing so, sky gardens can offer a more inclusive and welcoming environment, facilitating social interactions and contributing to a better quality of life for inhabitants (Bay, 2004; Pomeroy, 2013; Bay & Lehmann, 2017).

Future research should also explore the long-term impact of sky gardens on the social fabric of high-rise communities, focusing on how these spaces evolve and adapt over time. Additionally, studies should investigate the factors that contribute to the success or failure of sky gardens in fostering social interactions and providing restorative benefits (Timm et al., 2018). By understanding these factors, architects and urban planners can refine their designs to create more effective and sustainable communal spaces within high-rise developments.

In summary, Singapore's innovative approach to incorporating sky gardens and communal spaces in high-rise buildings demonstrates the potential for vertical urbanism to address the challenges of dense urban environments while promoting social sustainability and enhancing the quality of life for residents. The lessons learned from Singapore's experience can serve as valuable insights for other cities looking to adopt similar strategies in their urban development plans (Samant & Hsi-En, 2017; Bischeri & Micheli, 2016). By continually refining these designs and addressing the concerns of privacy, safety, and inclusiveness, sky gardens have the potential to become an integral part of the urban fabric in cities worldwide.

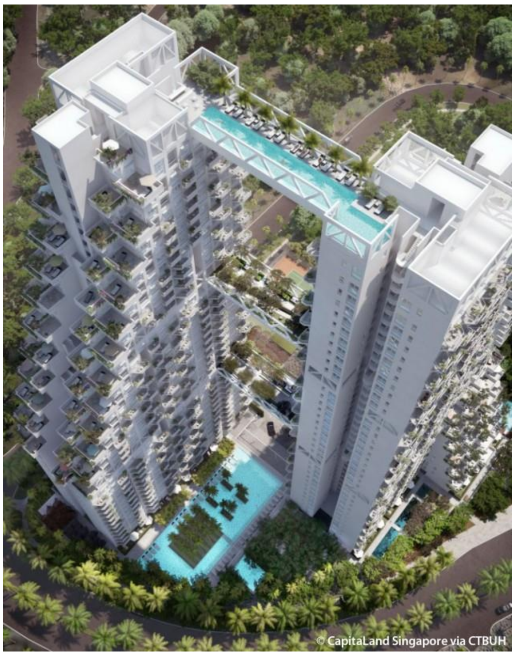


Figure 3.32 Sky Habitat sky gardens, by: Safdie Architects, source: Archdaily.

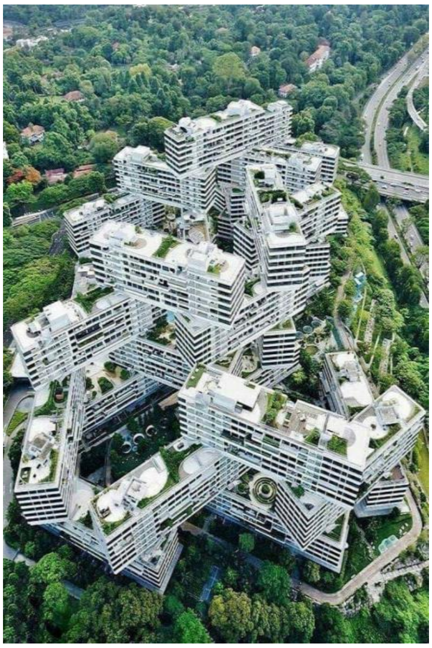


Figure 3.33 The Interlace Singapore, Source: OMA/Ole Scheeren

Figure 3.34 The Pinnacle@Duxton, Singapore. Source: Philip Oldfield

Figure 3.35 The Interlace Singapore, Source: OMA/Ole Scheeren

Figure 3.36 The Pinnacle@Duxton skygarden, Source: Christoph Ingenhoven

3.3. A Morphological Study of Elevated Urban Spaces

In the domains of urban planning and architectural design, the form of built environments is of significant consequence. This fundamental element not only influences the aesthetic character of the structures but also determines their functionality and adaptability. With the relentless expansion and increasing density of urban spaces, vertical solutions have come to the forefront of urban design, thus leading to the evolution of various forms of elevated urban spaces (Lehmann, 2016; Cho et al., 2015). This section categorises these elevated spaces into five main morphologies: Sky Gardens, Integrated Skywalks and Connected Sky Gardens, Courtscrapers, Rooftop Gardens, and Elevated Parks. Each category is scrutinised for its distinctive form, functional narrative, and notable global examples that represent these forms. A subsequent table provides an overview of these typologies, highlighting the potential these elevated structures have in shaping future urban landscapes (Table 3.1).

A crucial aspect that warrants consideration is the positioning and location of these spaces within tall mixed-use or hybrid buildings. The placement of sky gardens and communal spaces presents a significant challenge in terms of accessibility and vertical circulation (Cho et al., 2015; Oldfield, 2019). Moreover, achieving a balance between public accessibility and privacy also poses an intricate conundrum (Viñoly et al., 2015). Many tall buildings prefer to place public or semi-public Sky Gardens at their summit, attracting visitors with panoramic city skyline views. This not only serves as a city landmark but also offers a source of revenue for the building (Pomeroy, 2013). However, private sky gardens intended for the residents are usually found in the middle floors of such buildings. The building's form plays a crucial role in determining these spaces (Oldfield, 2019).

Buildings with tapering tops, such as 'The Shard', offer limited spaces for gardens and communal areas, requiring a rethinking of spatial allocation strategies (Cho et al., 2015). On the other hand, structures with larger top floors, like '20 Fenchurch Street', present opportunities for better-designed sky gardens (Samant & Hsi-En, 2017). The morphology of the ground levels of tall buildings also holds considerable importance. Buildings erected on a base or podium could create additional public roof gardens. In contrast, buildings raised on a substantial structure, such as Richard Rogers' '8 Chifley' building, can free up ground level for public use. Rogers pioneered this idea of raising the building, creating an accessible public space with direct visual access to various public building functions and amenities (Thompson, 2002).

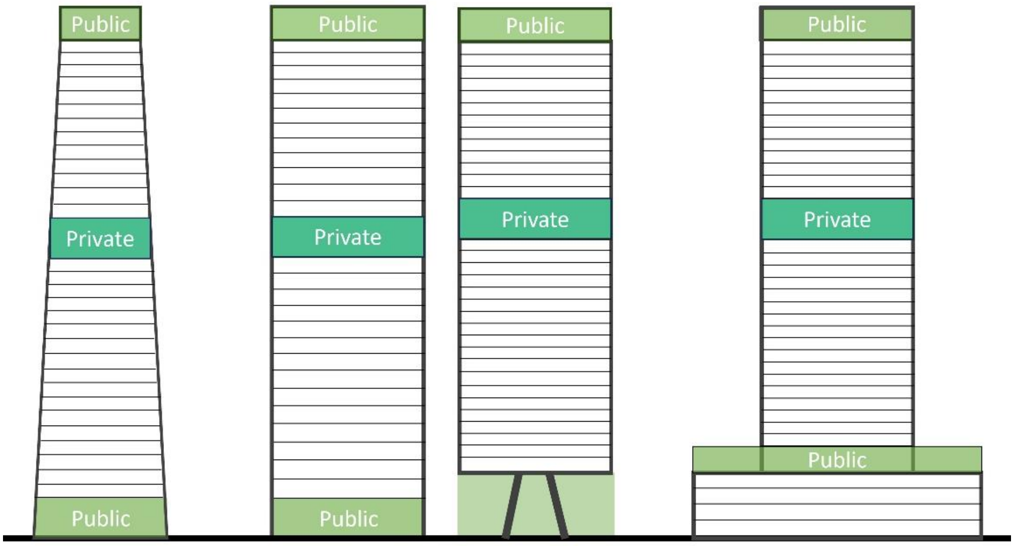
Integrated skywalks and connected sky gardens form another aspect of elevated urban spaces. This concept, widely embraced in Singapore, is attributed to Moshe Safdie, who successfully incorporated it into several of his projects, including 'The Marina Bay Sands', 'The Crystal', 'Orca', and 'Sky Habitat' (Samant, 2019; Wood & Safarik, 2019). These interconnected hybrid buildings generate a hierarchy of private and public sky gardens at different levels, creating a vibrant vertical community (Hadi et al., 2018).

The Courtscraper and pixelated towers represent an innovative typology in the design of elevated urban spaces within hybrid buildings (Lubin, 2016). The Courtscraper ingeniously blends the attributes of high-density American skyscrapers with the communal courtyards that are a distinctive feature of European residential architecture. This symbiosis offers a novel approach to introducing greenery and shared spaces in the context of high-rise urban dwellings. This inventive methodology has been applied in a number of buildings, with the primary objective of redefining the typology of high-rise living. The aim is to humanise the scale of high-rise buildings, transforming them into vertical urban forests (Lubin, 2016). This is achieved by transposing the concept of 'living in a house with a garden' onto a series of pixelated building blocks. These high-rise structures incorporate private green courtyards, terraces, and roof gardens, their design reminiscent of cities nestled in mountainous terrains. This concept has seen successful implementation in several notable projects such as the VIA 57 West building, Valley, Sky Habitat, and Bosco Verticale (Lehmann, 2016).

Rooftop gardens, a classic form of elevated urban spaces, provide versatile spaces that cater to diverse purposes, ranging from recreational activities to food production (Yuen & Hien, 2005). They also play a vital environmental role by offering green spaces that offset the building's carbon footprint. The public roof gardens of London are a testament to this, and it is not uncommon to find many older public buildings repurposing their roof levels into public roof gardens, often coupled with a bar, such as numerous car park buildings and former industrial buildings (Lindner & Rosa, 2017). Libraries, too, are following this trend, with the Library of Birmingham's rooftop garden being a well-known example.

Elevated parks are the final form of elevated urban spaces. Typically constructed above ground level on man-made structures like bridges and public transit stations, these parks offer a novel approach to urban green spaces (Littke et al., 2016). They not only provide city dwellers with a respite from the urban humdrum but also serve as corridors for pedestrian traffic, thereby reducing street-level congestion (Sinha, 2014). Prominent examples such as New York's High Line, Seoullo 7017, and Crossrail Place in London have transformed decommissioned infrastructural elements into vibrant urban habitats (Littke et al., 2016). This reutilisation of space not only addresses the issue of scarce land resources but also adds another layer to the cityscape. Consequently, elevated parks illustrate the remarkable potential for integrating nature within the dense fabric of urban environments.

Table 3.1: Morphological Study of Elevated Urban Spaces (Source: Author)

<table>
<tr><th>Elevated Urban Spaces</th><th colspan="4">Form</th></tr>
<tr><td rowspan="5">Sky Gardens (Mixed-use Sky Scraper)</td><td colspan="4">
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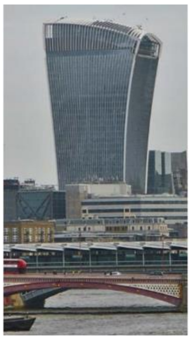
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>The Shard</td><td>20 Fenchurch Street</td><td>8 Chifley</td><td>Capita Green</td></tr>
<tr><td>
Qianhai Prisma West Tower</td><td>
Oasis Hotel</td><td>
18 Robinson</td><td>
Capita Spring</td></tr>
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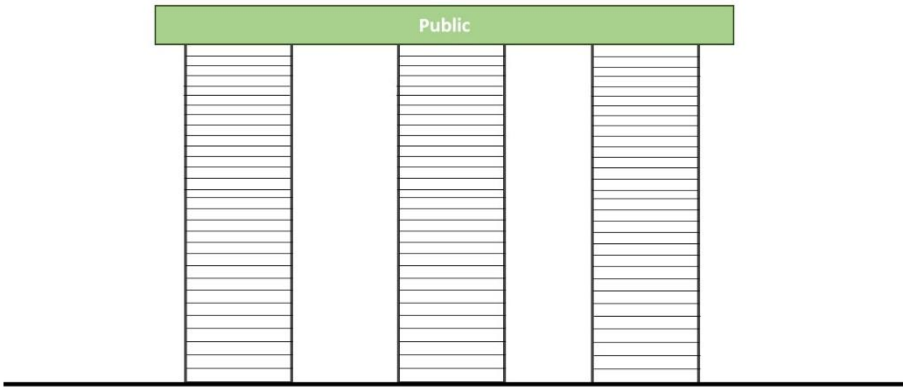
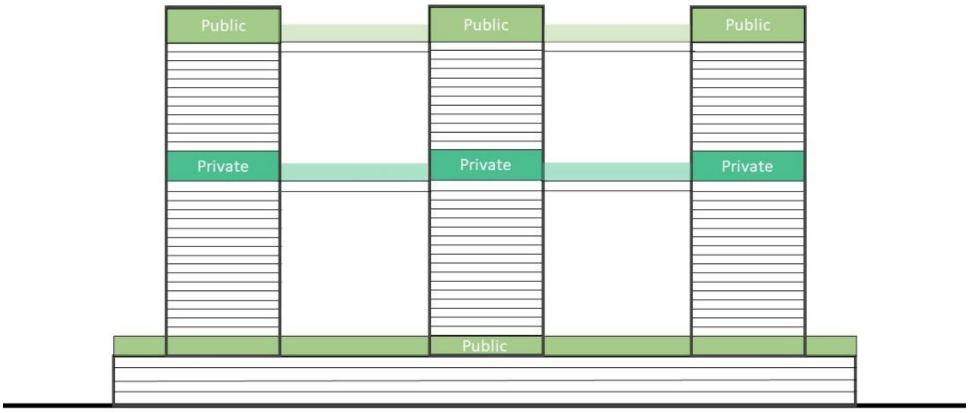
<tr><td rowspan="3">Sky Bridges & Connected Sky Gardens</td><td>





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<tr><td>Examples</td></tr>
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Linked Hybrid


Orca


Marina Bay Sands


The Crystal

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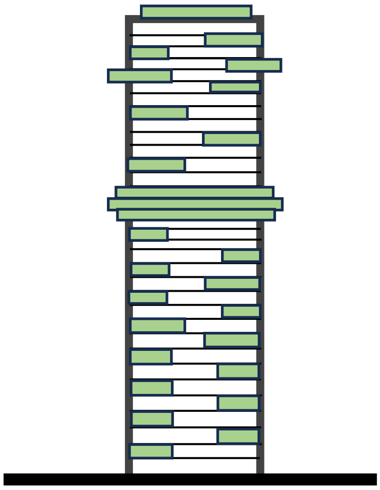
Court Scraper & Sky Courts

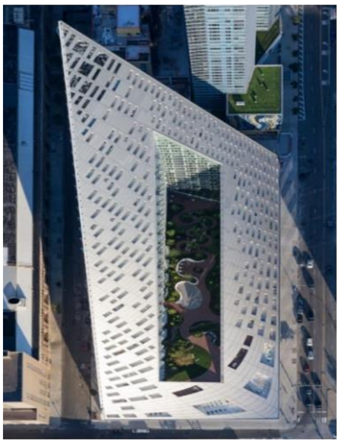


Examples

Valley

QORNER Quito

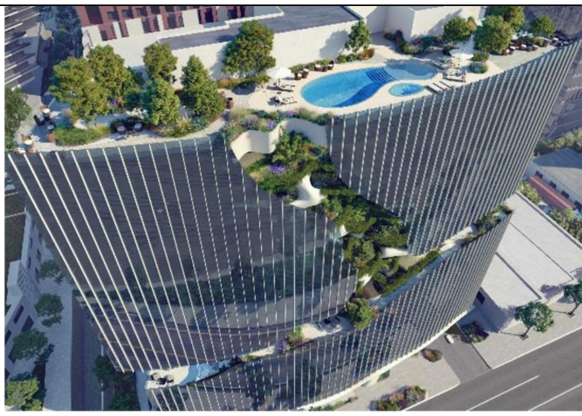
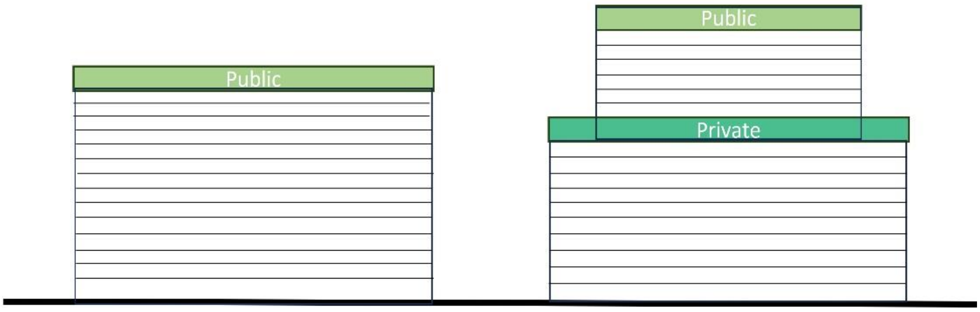
Empire City Tower



VIA 57 West Apartments

Bosco Verticale

Sky Habitat

	 Shenye TaiRan  One River North
Roof Gardens	
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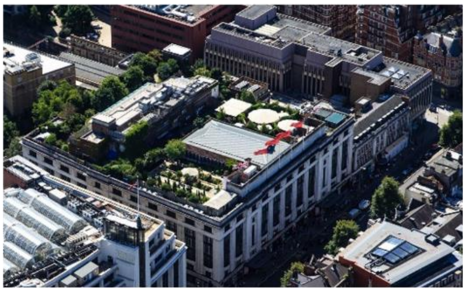
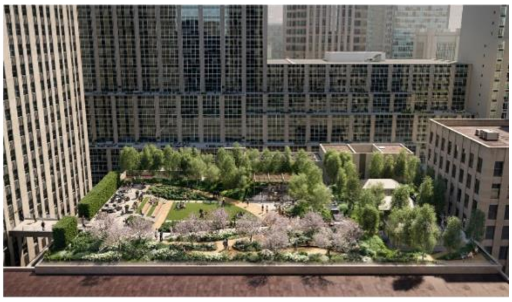
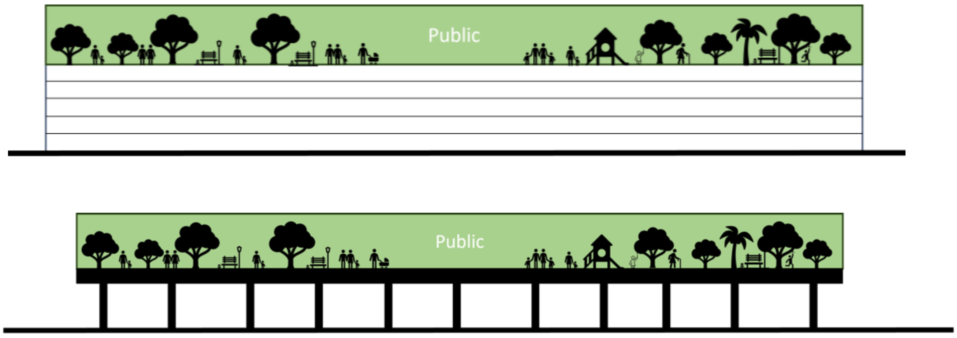
	 10 Fenchurch Avenue Building  Nieuwe Instituut  Kensington Roof Gardens  Radio City Musical Hall Rooftop Park

Birmingham Library Rooftop Garden

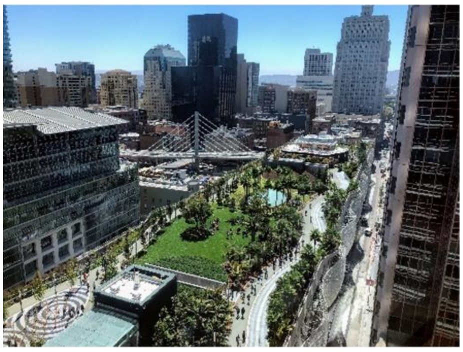
Elevated Parks



Examples

The High Line

Crossrail Place



Salesforce Park- Salesforce Transit Centre

Seoullo 7017

3.4 Biophilic Design and Elevated Social Spaces: Fostering Resilience in High-Density Cities During Pandemics

The COVID-19 pandemic has brought to the forefront the crucial role of green spaces and biophilic design in promoting mental health and well-being, particularly in high-density urban environments. Green spaces, defined as natural or semi-natural areas within urban settings, contribute significantly to psychological well-being by providing a refuge from the built environment and fostering a connection to nature (Berman et al., 2012; Hartig et al., 2014). The concept of biophilia, introduced by Wilson (1986) and expanded upon by Kellert and Wilson (1995), postulates an innate human affinity for nature, suggesting that incorporating natural elements into our surroundings can have positive effects on mental health (Wilson, 2017; Schertz & Berman, 2019) . During the pandemic, access to green spaces and exposure to natural elements has been shown to mitigate the adverse psychological impacts of lockdowns and social isolation, such as anxiety, depression, and stress (Ugolini et al., 2020).

Mental health is of paramount importance to an individual's overall well-being and is influenced by a myriad of factors in our lives. As defined by Galderisi et al. (2015), mental health pertains to the successful mental functioning of an individual, enabling the realisation of one's abilities. This encompasses the maintenance of productive daily activities, the sustenance of gratifying interpersonal relationships, and the capacity to adapt to change and manage stress (Mechanic, 1999). The recent global pandemic has had a significant impact on the mental health of young people, with studies demonstrating heightened levels of anxiety and depression (Varma et al., 2021). A comprehensive dataset on mental health from the UK revealed that one in five participants exhibited depressive symptoms necessitating clinical intervention, while approximately 15 per cent met the criteria for a clinical anxiety disorder (Office for National Statistics, 2021).

Historically, pandemics have often triggered substantial alterations in urban settlements' landscape. Renowned landscape architect Frederick Law Olmsted was a fervent advocate of parks, deeming them the 'lungs of the city'. During the late 19th century, it was widely believed that parks could alleviate communicable diseases and mitigate other societal issues (Beveridge & Rocheleau, 1995). A contemporary study investigated the relationship between time spent in green spaces and perceived mental health and vitality. Data was collected via surveys across four European countries, including the UK, and the findings demonstrated that individuals residing in areas with abundant green spaces reported superior physical and mental health compared to those living in less verdant environments. The results suggest that increased exposure to green spaces correlates positively with vitality and mental health, irrespective of climatic and cultural factors (Van den Berg et al., 2016).

In Auckland, New Zealand, another study examined the association between the proximity of green spaces and mental health. The research concluded that reduced distance from home or workplace to accessible green spaces, and a higher proportion of green spaces in the broader neighbourhood, were linked to decreased anxiety and mood disorder treatment counts within an urban setting (Nutsford et al., 2013). These findings imply that the advantages of green spaces on mental health may stem from both active engagement in accessible green spaces near one's residence and the mere presence of observable green spaces in the surrounding neighbourhood (Astell-Burt et al., 2013; Cohen-Cline et al., 2015).

Addressing the complexities of safeguarding public health during contemporary and forthcoming pandemics poses a considerable challenge, particularly in relation to spatial density. As urban planners and designers deliberate the future development of public spaces, they must grapple with various concerns, such as the accommodation capacity of these spaces and the dynamics of human co-occupancy (Megahed & Ghoneim, 2020; Robinson, 2020). In 2020, measures to curb the spread of COVID-19 led to the taping of park benches, thereby discouraging group gatherings. As restrictions began to ease in 2021, a wide array of institutions, from intimate jazz clubs to sprawling outdoor sports arenas, continued to enforce rigorous infection-control protocols, often exceeding traditional Fire Department regulations, with the threat of closure looming for non-compliant establishments (Douglas et al., 2020).

During the 2020 lockdowns in countries like Spain, Italy, and France, residents demonstrated remarkable ingenuity in adapting apartment balconies as platforms for social engagement. These vertically organized micro-spaces formed a "hive" that enabled inhabitants to maintain safe social distances while partaking in shared experiences (Gupta, 2020). This innovative three-dimensional social interaction encompassed various aspects of daily life, including familial support, greetings, and cultural entertainment. The importance of these balcony spaces for mental well-being became increasingly apparent, extending beyond their primary functional roles (Pouso et al., 2021; Peters & Halleran, 2021).

Drawing on insights from pandemic-induced lockdown experiences, it is clear that the design of public spaces must not only prioritize enjoyment but also address the critical need to maintain appropriate density levels during periods of heightened risk. Striking a balance between fostering pleasurable experiences and adhering to essential social distancing measures is crucial for the continued safety and well-being of urban populations.

High-density cities, where access to green spaces is often limited, may exacerbate the negative effects of pandemics on mental health (Amerio et al., 2020). The scarcity of green spaces in these environments intensifies the need to explore alternative typologies that can serve as social and public spaces, providing inhabitants with opportunities to connect with nature and one another (Luo et al., 2021; Alhusban et al., 2022). Elevated green spaces, such as roof gardens, elevated parks, sky courts, and sky gardens, have emerged as innovative solutions that capitalize on underutilized vertical spaces, thus circumventing the constraints imposed by limited ground-level availability (Samant, 2019; Pomeroy, 2013; Yang et al., 2015).

Elevated green spaces not only address the need for biophilic connections in high-density cities but also provide additional benefits in the context of pandemics and beyond (Reinwald et al., 2021; Akbari et al., 2021). These spaces can facilitate social distancing by distributing users across multiple levels, thereby reducing crowding and the risk of viral transmission (Amerio et al., 2020; Manso et al., 2021). Moreover, elevated green spaces contribute to urban biodiversity, air quality improvement, and climate change mitigation, further enhancing their potential to promote human and environmental health (Yang et al., 2015; Li et al., 2022).

In light of the ongoing pandemic and the potential for future health crises, the incorporation of elevated green spaces in high-density urban environments warrants increased attention from urban planners, architects, and policymakers. By embracing these innovative typologies, cities can cultivate resilient, healthy, and sustainable environments that support the mental well-being of their inhabitants in times of crisis and beyond (Hartig et al., 2014; Oldfield 2019).

Amidst the ongoing pandemic and potential future health crises, the integration of elevated green spaces in high-density urban environments necessitates heightened attention from urban planners, architects, and policymakers (Luo et al., 2021; Manso et al., 2021). By adopting such innovative typologies, cities may cultivate resilient, salubrious, and sustainable environments that bolster the psychological well-being of inhabitants during challenging times and beyond (Hartig et al., 2014; Oldfield 2019).

Notwithstanding the myriad advantages and potential benefits of these elevated green spaces, their sustained presence is jeopardised by the myriad challenges encountered during the pandemic and ensuing lockdowns (Jens & Gregg, 2021; Geng et al., 2021). A multitude of these spaces were provisionally closed to safeguard visitors' health and well-being, thereby accentuating the limitations of extant designs in relation to accessibility, circulation, health and safety, management, inclusivity, security, privacy, and the facilitation of social interactions (Cheshmehzangi, 2020; Borowski & Stathopoulos, 2023). To guarantee the endurance and resilience of elevated green spaces, future research must endeavour to develop comprehensive guidelines and design schemas addressing these limitations (Bojović, et al., 2022; Cho et al., 2015). Specifically, studies should strive to enhance understanding of human behaviour and interactions within these spaces, thereby facilitating the creation of efficacious design models and best practices for establishing resilient and sustainable elevated social spaces (Xie et al., 2020; Honey-Rosés et al., 2021).

3.5 Elevated social spaces in London between success and failure

The advent of elevated social spaces in London has garnered considerable scholarly interest, as they introduce a novel classification of public space within the urban fabric. These spaces present a unique opportunity to integrate elements of nature, illumination, and greenery into densely populated metropolitan areas, thereby offering a sanctuary from the city's frenetic pace. However, the realization of these spaces necessitates addressing a myriad of challenges to ensure their viability and long-term success.

Since the inauguration of the world's first underground railway network in 1863, London has been a multi-layered city (Aleta et al., 2017; Madanipour, 2019). In the 21st century, it has undergone a transformation into a 'skyscraper city' with an increasing number of towers exceeding 100 metres in height, some of which feature elevated urban spaces (Morato, 2022; Viñoly et al., 2015).

The innovative concept of elevated gardens has been implemented and evaluated in several completed projects, such as the Sky Garden at 20 Fenchurch Street, The Garden at 120 Fenchurch Street, and Crossrail Place at Canary Wharf. As these spaces become integrated into the city's public space portfolio, ongoing debates surround their potential to function as vibrant and inclusive urban spaces (Wood & Safarik, 2019; Hadi et al., 2018). London now boasts various examples of elevated social spaces, including sky gardens, roof gardens, elevated parks, sky courts, and elevated walkways, each governed by its own set of rules and regulations (Table 3.2). Although many of these spaces were initially offered as public spaces, the COVID-19 pandemic has had significant impacts on their operation, resulting in the closure or modification of some spaces to comply with health and safety regulations.

Table 3.2: Elevated social spaces in London (Source: Author)

Name	Type and Functions	Building Name and Functions	Access and Location	Privacy and Accessibility	Image
Sky Garden	Sky Garden	20 Fenchurch Street (The Walkie-Talkie)	Floor: 35-37, 20 Fenchurch Street,	Accessible with free entry ticket (pre-booking required)	  
	Viewing platform, restaurant, bar, event space, garden	Office, Mixed-Use	Lifts	Security gates check in required	

The Shard Sky Deck	Sky Deck	The Shard	Floor: 72, The Shard, 32 London Bridge St, London	accessible with entry fee (booking required)	  
	Viewing platform, events	Mixed use (Office, hotel, restaurants, Viewing deck)	Lifts	Security gates check in required	
The Garden at 120	Roof Garden	One Fen Court	Floor: 15, One Fen Court, 120 Fenchurch Street	Accessible with free entry (no booking required)	  
	Viewing platform, garden, seating area	Mixed use (office and retail)	Lifts	Security gates check in required	

The Roof Terrace at Queen Elizabeth Hall	Roof Garden	Queen Elizabeth Hall	Floor: 3, Queen Elizabeth Hall Southbank Centre	Accessible with free entry (no booking required)	  
	Garden, seating area, outdoor bar	Cultural, Performing Arts Venue	Lifts and stairs	No security gates	
Crossrail Place Roof Garden	Elevated pocket park	Crossrail Place	Floor: 4, Crossrail Place, Canary Wharf	Accessible with free entry (no booking required)	  
	Garden, seating area, event space, amphitheatre, bar and restaurants	Mixed-Use (Retail, Office, Canary Wharf rail way station)	Lifts and escalators	No security gates	

Barbican Beech Gardens	Elevated park	Barbican Estate	High Walk level, Barbican Estate, Barbican	Accessible with free entry (no booking required)	  
	Garden, seating area, walkways	Mixed-Use (residential, cultural)	Lifts and stairs	No security gates	
Aga Khan Islamic Gardens	Roof Garden and interconnected Terraces	Aga Khan Centre	Floors: 3, 4, and 7, Aga Khan Centre, 10 Handyside Street	Accessible with free entry (no booking required)	  
	Garden, Islamic cultural experience, event space	Cultural Institution	Lifts	No security gates	

The Roof Park	Roof Garden	Bootstrap Building	Floor: 2, Bootstrap Building, Dalston	Accessible with free entry (no booking required)	  
	Garden, seating area, event space, workspace	Mixed use (community and workspace areas)	Lifts and stairs	No security gates	
John Lewis Roof Garden	Roof Garden	John Lewis & Partners Oxford Street	Floor: 5, John Lewis & Partners, Oxford Street,	Accessible with free entry (no booking required)	  
	Garden, seating area, seasonal events	Retail	Lifts and escalators	No security gates	

Kew Gardens Aerial Walkway	Elevated Walkway	Kew Gardens	Kew Gardens, Richmond	Accessible with garden entry fee (no booking required)	  
	Walkway, tree canopy exploration, nature experience	Royal Botanic Gardens	Stairs	No security gates	
Coutts Skyline Garden	Roof Garden	Coutts Bank Building	Floor: 6, Coutts Bank Building, 440 Strand	Private, accessible for Coutts employees and clients only,	  
	Garden, event space, sustainable showcase	Mixed use (Bank, office building and roof garden)	Private lift, which requires an access card to operate	Security gates	

The future of these spaces remains a subject of considerable debate among scholars. Proponents argue that elevated social spaces can foster functional, sustainable urban spaces capable of accommodating and responding to diverse, intense, hybrid, dynamic, and unprecedented urban conditions, particularly in the context of recent or future pandemics. Advocates emphasize the need to reimagine public spaces in a three-dimensional context, suggesting that activating the vertical public realm through roof gardens, sky gardens, and elevated parks could significantly reduce travel distances and enhance the concept of 15-minute neighbourhoods in high-density cities such as London. Conversely, critics highlight the limitations and challenges that must be studied further in order to develop resilient elevated social spaces. These challenges encompass aspects such as accessibility, circulation, space design, security, safety, and management, necessitating the development of innovative, interactive design frameworks to address them effectively.

Recently, sky gardens have become a defining feature of some of London's tallest buildings, offering a unique opportunity to enhance the city's skyline. The Sky Garden at the top of the 20 Fenchurch Street (Walkie Talkie) building was initially marketed as a public park, located 150 metres above the city. While it manages to draw in hundreds of visitors each day, the process to gain access to this space necessitates advance online reservations and stringent security checks akin to those at airports, prompting some critics to categorise it as an exclusive space that can only be accessed by appointment (Reinke, 2015).The former Mayor of London, Boris Johnson, produced a manifesto for public spaces, entitled "London Great Outdoors", in which he argued that there has been an increase in private management of publicly accessible spaces. According to the manifesto, when this type of corporation occurs, particularly in large commercial developments, Londoners can feel excluded from parts of their own city (Carmona, 2014).

The data reveals that some of the most renowned elevated social spaces in London include The Shard Sky Deck, Sky Garden, The Garden at 120, and Crossrail Place Roof Garden. These spaces have gained popularity due to their distinctive features, such as viewing platforms, gardens, and event spaces. Their strategic placement within iconic buildings or central areas of the city further bolsters their prominence. In this analysis, we will explore the opportunities and challenges each space presents, considering accessibility, security, management, booking fees, activities, space design, and the impact of the COVID-19 pandemic.

The Shard Sky Deck, for example, boasts unparalleled 360-degree views of London from the city's highest viewing platform, captivating both tourists and locals. This elevated space is part of the UK's tallest building, The Shard, adding to its appeal and making it a must-visit destination. However, challenges in terms of accessibility from the ground level, entry fees, and required booking may limit some visitors' ability to experience this iconic location. During the COVID-19 pandemic, the space likely faced temporary closures or capacity restrictions, potentially impacting its revenue and visitor numbers.

Sky Garden, located within the striking "Walkie-Talkie" building, offers a unique combination of verdant greenery, a sophisticated restaurant, a stylish bar, and event spaces. This captivating blend of elements provides visitors with a multisensory experience that has solidified Sky Garden's fame. The indoor garden spans three storeys, featuring a variety of plants that create a lush, tranquil environment for visitors to enjoy amid the bustling cityscape. Its remarkable design and location make it a popular attraction for both tourists and residents seeking a distinctive experience. However, the requirement of pre-booking and security checks for entry might deter some visitors. Like other public spaces, Sky Garden may have experienced temporary closures or adaptations in response to the COVID-19 pandemic, such as social distancing measures and reduced capacity.

The Garden at 120 presents a more intimate setting, featuring a roof garden and seating areas where visitors can unwind and appreciate views of the city. Its sleek design incorporates wooden seating, water features, and pergolas, making it an inviting space for relaxation and socialising. This elevated space's charm is further enhanced by its easy accessibility and free entry, attracting a diverse range of visitors. Nevertheless, the space may still face challenges related to security and management. The COVID-19 pandemic might have necessitated adjustments to its operations, such as implementing hygiene measures or limiting visitor numbers.

Similarly, the Crossrail Place Roof Garden provides a unique elevated pocket park experience with an amphitheatre, gardens, and event spaces, forming a sanctuary for visitors within the bustling Canary Wharf area. The innovative design of this roof garden, featuring a semi-transparent roof structure, allows for year-round use and creates a microclimate that supports a diverse range of plant species. Its integration with the surrounding retail and office spaces makes it an attractive destination for both local workers and visitors seeking respite from the urban environment. Challenges such as maintaining accessibility and safety in a busy commercial area may arise. The space would have likely had to adapt during the COVID-19 pandemic, potentially adjusting its activities, events, and capacity to comply with safety guidelines.

In conclusion, these elevated social spaces in London have achieved prominence and popularity through their unique features, strategic locations, and appealing design elements. Spaces such as The Shard Sky Deck and Sky Garden offer breathtaking views and one-of-a-kind experiences, while The Garden at 120 and Crossrail Place Roof Garden provide intimate and inviting environments for relaxation and engagement. Their continued success can be attributed to their ability to cater to diverse visitor interests and needs, making them essential components of London's vibrant urban landscape. However, they also face challenges related to accessibility, security, management, and the effects of the pandemic.

The outcome of vertical public life is contingent on both the design of the building and the actions of building owners and operators in terms of balancing the governance of these spaces. It is imperative to strike a balance between providing sufficient security measures to ensure the safety and comfort of building users and residents, while also promoting public freedom and fostering social interaction through the implementation of flexible rules. This underscores the importance of establishing guidelines and regulations for the use and operation of sky gardens and communal spaces as venues for community and social interaction.

Wood (2014) proposes a solution to these challenges through the concept of a public-private partnership, in which local government assumes responsibility for the spatial and public infrastructure within towers in a similar manner to its responsibility for street, park, and square infrastructure at ground level. Although this approach may be considered radical, it holds the potential to offer a diverse array of programs and experiences within a skyscraper. However, it is possible that local government may not be inclined to assume responsibility for these spaces due to the growing trend towards private management of publicly accessible spaces.

3.5.1 Critical Factors Affecting the Design of Elevated Social Spaces

Elevated social spaces can be characterized by their distinct spatial morphology, which serves to alleviate the perceived density of tall buildings or high-density developments (Pomeroy, 2013). This is achieved through the fragmentation of the mass and repetition of floor plates, resulting in an environment that evokes the human scale and proportion commonly found in traditional streets within high-density urban habitats. The creation of such spaces leads to the formation of hybrid buildings that strike a balance between form and function, thus contributing to the development of more liveable and sustainable urban environments (Al-Kodmany, 2020).

Ken Yeang is broadly acclaimed as a forerunner in the sphere of vertical urban design, having introduced a foundational architecture for this orientation in his postulation of a 'vertical theory of urban design'. Yeang posits that the sheer scale of skyscrapers necessitates a paradigm shift, with a concentration on urban design rather than purely on architectural form-creation (Yeang, 2002; Generalova & Generalov, 2020). In this framework, exterior spaces define the urban form and its borders, and the key attributes of a vertical public realm include its enclosed character and the integration of free-flowing landscape elements for daylight and natural ventilation. To effectively serve their purpose as social spaces, elevated public realms must be designed with a deep understanding of human behaviour, incorporating properties of shape and scale to create spaces that are not only vast and formless, but also carefully crafted and meaningful (Hanzl & Ledwon, 2017).

Accessibility is a crucial challenge in the realm of elevated social spaces, encompassing not only physical accessibility but also visual accessibility (Carmona, 2019). As these spaces are often situated at the higher levels of structures, both tall and medium-rise, it is important to provide efficient means of access through the implementation of escalators, ramps, lifts and stairways. However, it is equally essential to ensure that the access routes are secure, safe, and accommodate the needs of all users, including those with disabilities (Aleta et al., 2017).

The movement patterns of pedestrians in vertical social spaces differ significantly from those in the city, where the vertical public realm primarily operates as a car-free environment. To design a thriving vertical public realm, it is necessary to consider not only the intended destination, but also the crucial role of the journey in fulfilling social, economic, and environmental objectives (Mehta, 2014). This requires the development of a movement framework that prioritizes accessibility while minimizing the reliance on mechanical transportation and takes into account the movement demands and the need to integrate new areas with existing networks (Aleta et al., 2017).

In addition to physical accessibility, visual accessibility also plays a crucial role in elevating the social spaces as it enhances the users' experience of the environment. Providing clear and unobstructed views of the surrounding area can create a sense of connection and belonging, as well as encourage social interaction and engagement among users. Thus, visual accessibility should be considered when designing elevated social spaces, in order to foster vibrant and inclusive urban environments (Moore, 2021).

The COVID-19 pandemic has presented numerous challenges to urban planning and design, particularly in the context of elevated social spaces within London. These challenges have not only impacted the operational aspects of such spaces, but have also raised questions regarding the resilience of their design and the capacity for adaptation in the face of public health crises (Afrin et al., 2021). This research problem, therefore, aims to investigate the effects of the pandemic on the design of elevated social spaces and the necessity for the development of resilient design strategies to ensure their continued functionality and accessibility.

The objective of this PhD thesis is to critically examine the implications of the COVID-19 pandemic on the design, regulation, and resilience strategies of elevated social spaces in London. During the pandemic, spaces such as The Shard Sky Deck and the Sky Garden experienced temporary closures and operational disruptions, prompting a re-evaluation of their capacity to adapt to changing public health guidelines. Furthermore, the pandemic significantly altered user behaviour, with individuals increasingly seeking open spaces that permitted social distancing and minimized the risk of viral transmission.

This research aims to assess the various adaptive measures employed by elevated social spaces during the pandemic, including the implementation of timed entry systems, reduced visitor capacity, and mandatory pre-booking to manage crowds and maintain social distancing. Additionally, the study will explore how these spaces responded to shifts in visitor preferences by examining the increased popularity of open-air locations such as The Garden at 120 and Crossrail Place Roof Garden.

Furthermore, this investigation will delve into the design adaptations made in response to COVID-19, focusing on the incorporation of hygiene and social distancing measures. Such adaptations may include the installation of sanitization stations, reorganization of seating arrangements, and the implementation of one-way foot traffic systems. The overarching goal of this research is to identify resilient strategies that can be incorporated into the planning and development of elevated social spaces to prepare for potential future public health crises.

In summary, the research problem and objective of this PhD thesis centres on the impact of the COVID-19 pandemic on the design of elevated social spaces in London, with particular emphasis on the need for resilient design strategies and schemas. Through a comprehensive analysis of the pandemic's effects and the subsequent adaptations made by these spaces, this research seeks to contribute valuable insights to the field of urban planning and design, ultimately promoting the development of adaptable and resilient elevated social spaces capable of weathering future challenges.

3.5 Chapter Summary

Chapter 3 of this thesis offers an extensive literature and contextual review of elevated social space design, with a focus on the implications of the post-Covid and future pandemic context. The chapter addresses various themes such as density, hybrid urban spaces, the history of vertical urban spaces, biophilia, and the importance of fostering freedom to roam, view, and breathe in these spaces to promote mental health. The chapter highlights Singapore's approach to designing vertical green social spaces as a noteworthy precedent and provides insights into design qualities of vertical urban spaces, including accessibility, publicness, activities, circulation, biophilic offerings, design, and management.

The chapter further examines the impact of the Covid-19 pandemic on the design of elevated social spaces and the potential influence of future pandemics. A macro-scale analysis of sustainable elevated green social spaces offers a global overview and various approaches, while a micro-scale analysis focuses specifically on London.

This chapter contributes to the ongoing discourse surrounding elevated social space design, underscoring its potential to bolster physical, mental, and social wellbeing in the context of dynamic urban environments. By scrutinizing the challenges, limitations, and opportunities associated with elevated social spaces in London, this thesis aims to furnish urban planners and designers with valuable insights applicable in a post-Covid and future pandemic context. The comprehensive analysis of various themes and case studies seeks to inform the design of versatile and resilient elevated social spaces that accommodate evolving social, public health, and mental health needs.

In conclusion, this chapter lays the foundation for the research problem and objective of the PhD thesis, focusing on the repercussions of the Covid-19 pandemic on the design of elevated social spaces in London. Through an in-depth examination of the pandemic's impacts and the subsequent adaptations undertaken by these spaces, this research endeavours to provide invaluable insights to the realm of urban planning and design, ultimately fostering the development of adaptable and resilient elevated social spaces equipped to confront future challenges.

Chapter 4: Immersive Virtual Reality in Urban Design - A Study of Tools and Challenges

4.1 Introduction

This chapter of the thesis focuses on the use of co-design methods, specifically the integration of Extended Reality (XR) technologies, in the design of public and social spaces. The research presented in this chapter provides an in-depth analysis of the current state of immersive XR technologies, with a specific emphasis on Virtual Reality (VR), in elevated social spaces design.

The significance of VR in the design process is highlighted, as it represents a key tool for exploring human behaviour and interaction with the designed space. The chapter provides a comprehensive overview of the various VR tools, software, and applications currently available in the market, exploring the gaps, opportunities, and challenges associated with their use in urban design and public space design. The use of VR as a design tool is examined in detail, with a focus on its potential to enhance the design process and improve community engagement. By investigating the role of VR in elevating the quality and impact of public spaces, this chapter aims to provide a comprehensive understanding of its implementation in the urban design process, while addressing the critical aspects of its use.

In conclusion, this chapter serves as a literature review to the innovative VR tools and applications in architecture and urban design, providing a thorough examination of the use of co-design and VR technologies in the design of public and social spaces (Figure 4.1). The research presented in this chapter provides a foundation for understanding the potential of these technologies to improve the design quality and impact of elevated social spaces.

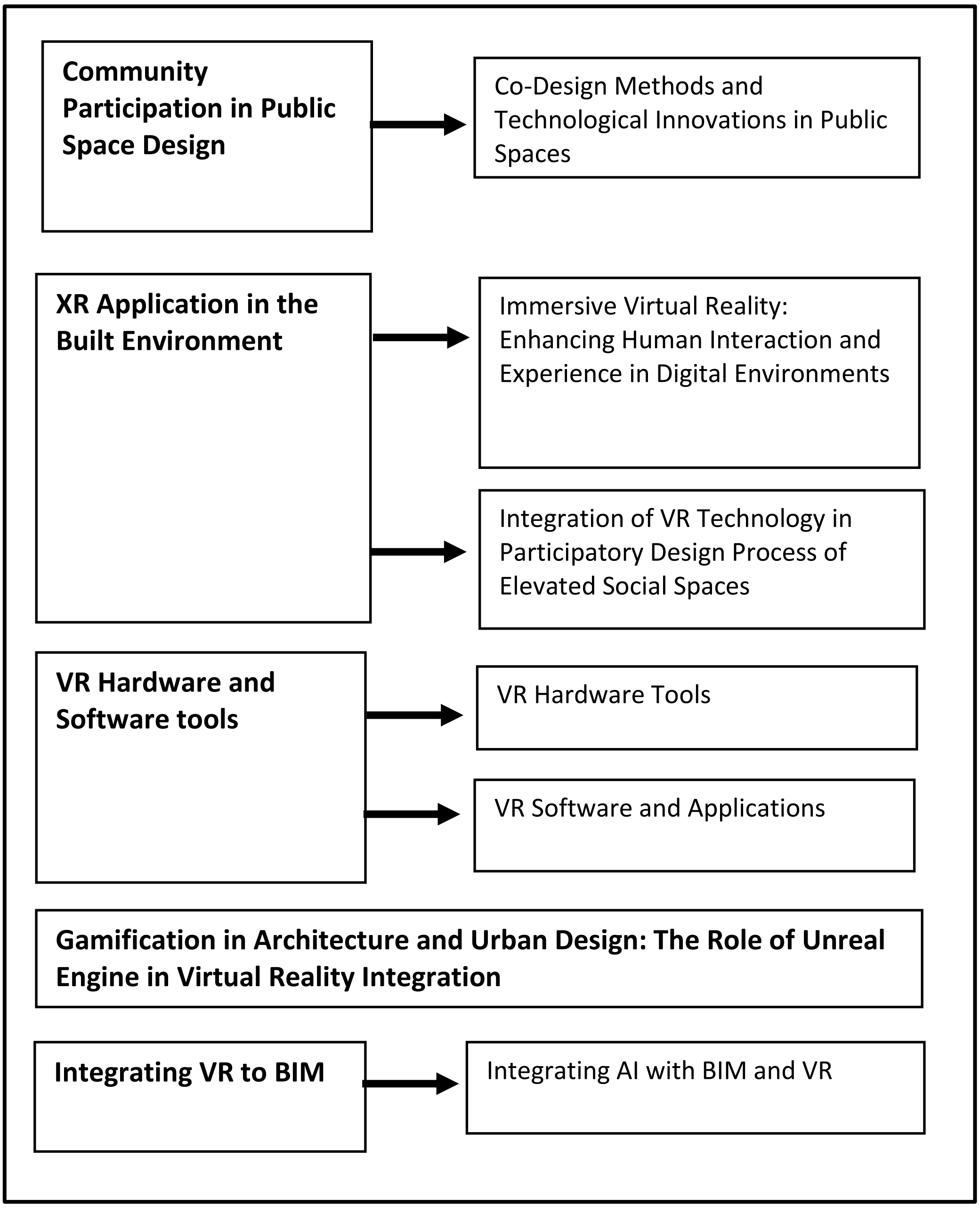


Figure 4.1: Diagram illustrating the primary sections covered in Chapter 4 (Source: Author)

4.2 Community Participation in Public Space Design

The evolution of architectural and urban design practices has long been dominated by specialised professionals, with minimal public involvement (Brain, 2019; Fischler, 2012; Carmona et al., 2010). Yet, a growing awareness of the significance of designing spaces that reflect the needs and aspirations of their occupants has sparked an increased interest in engaging the public in the design process (Ismail et al., 2015; Sanoff, 2000). This interest is founded on the belief that public involvement can contribute to higher-quality designs and, consequently, increased user satisfaction (Ho et al., 2021; Arnstein, 1969).

Public participation encompasses the engagement of community members in decision-making processes that influence their lives, communities, and surroundings (Evans-Cowley & Hollander, 2010). The underlying principle of public participation is that citizens are entitled to actively participate in decision-making processes relevant to them, beyond merely exercising their right to vote (Burton, 2009; Dougherty & Easton, 2011; Kenawy & Ehab, 2015). Within the realm of urban design, public participation seeks to foster enhanced transparency, accountability, and democratic governance by ensuring that the viewpoints and insights of all stakeholders are considered (Amado et al., 2010; Levenda et al., 2020).

The incorporation of public participation in architectural and urban project design and execution is widely recognised as a vital element in crafting spaces that cater to the needs and preferences of their users (Wilson et al., 2019; Amado et al., 2010). Public participation in urban design entails the active engagement of community members throughout the design process, allowing them to voice their opinions, provide feedback, and contribute ideas that shape the final design (Wates, 2014; Nabatchi et al., 2015). This approach has the potential to yield designs that more accurately represent the community's needs and desires, ultimately resulting in increased user satisfaction and greater utilisation of public spaces (Wilson et al., 2019; Bednarska-Olejniczak et al., 2019).

One technique employed in public participation within urban design is the use of collaborative design or co-design workshops (Stelzle et al., 2017; Huusko et al., 2018). City officials, design professionals, and researchers have extensively utilised these workshops as a means of effectively engaging local stakeholders in urban processes, such as neighbourhood regeneration schemes (Eraydin, 2012). A typical co-design workshop comprises a series of structured activities designed to foster a mutual understanding of the challenge at hand and to generate ideas for potential design solutions that better reflect the local population's needs and preferences (Calvo & Sclater, 2021; Sanoff, 1999; Carroll & Nørtoft, 2022).

Co-design constitutes a collaborative approach to urban design that unites designers, stakeholders, and the general public in a collective effort to develop solutions for diverse urban challenges, including public spaces, infrastructure, transportation, and community development (Sanders et al., 2010; Webb et al., 2018). This methodology (Figure 4.2) aims to promote inclusivity and diversity by incorporating perspectives from various parties involved, ultimately creating culturally and socially relevant, sustainable, and responsive spaces (Manzini & Rizzo, 2011). Co-design workshops, which typically involve structured activities, facilitate a shared understanding of challenges and generate ideas for potential solutions (De Siqueira et al., 2022; Sanders & Stappers, 2008). Applied across various urban processes, co-design employs a range of tools and techniques, from manual methods to innovative digital tools, to enable active participation and foster participatory and interactive urban dialogues (Stelzle et al., 2017; Bannon & Ehn, 2012; De Lange & De Waal, 2017). As a crucial component for addressing social equity, co-design ensures that the needs and perspectives of marginalised groups are taken into account, fostering more diverse and inclusive spaces and leading to superior design outcomes (Fainstein, 2014).

The notion of co-design in public spaces has garnered increasing attention in recent years, as it represents a promising approach to creating spaces that are inclusive, accessible, and responsive to the needs and desires of the community (Manzini & Rizzo, 2011; Calvo & Sclater, 2021). Co-design involves collaboration between designers and users to co-create spaces that embody the values, aspirations, and identities of the community (Sanders & Stappers, 2008, 2014). This participatory design approach seeks to incorporate user perspectives, experiences, and ideas into the design process, resulting in spaces that are not only functional and aesthetically appealing but also more likely to be embraced and used by the community (Munthe-Kaas, 2015).

In contrast to traditional design approaches, which have often been criticised for their top down, prescriptive, and insensitive nature towards users' needs and desires, co-design adopts a user-centred approach that prioritises the integration of user perspectives and experiences into the design process (Brown & Wyatt, 2010). This approach has the potential to create spaces that are more responsive to user needs and are more likely to be used and valued by the community.

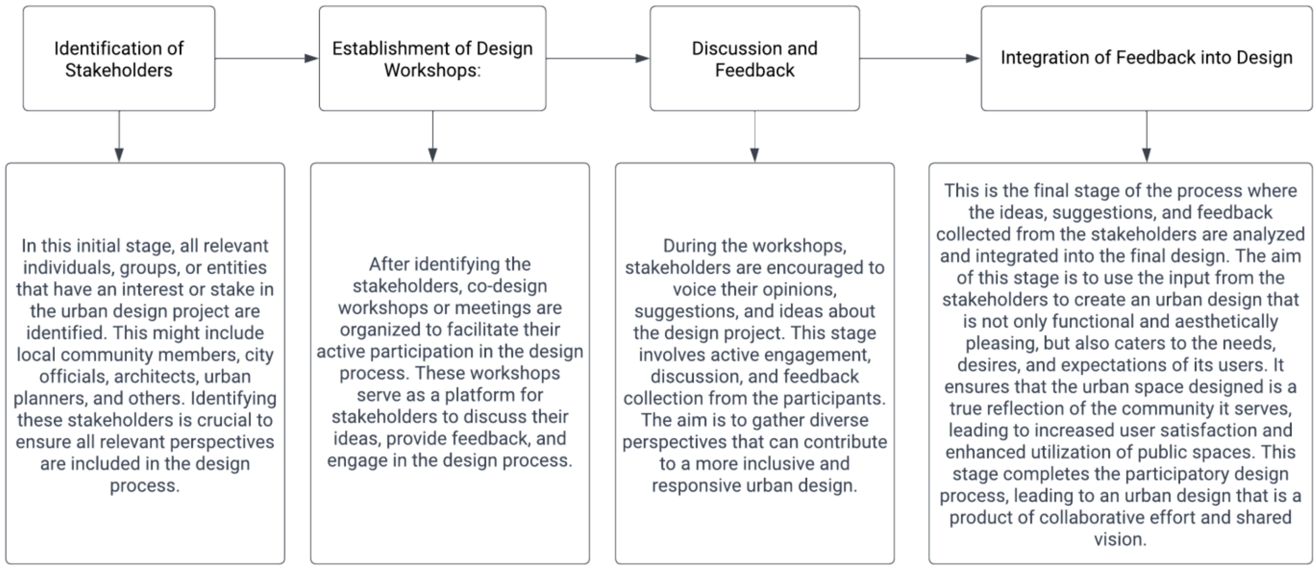


Figure 4.2: A flow chart illustrating the process of public participation in urban design (Source: Author)

4.2.1 Co-Design Methods and Technological Innovations in Public Spaces

In the realm of public space design, various co-design methodologies can be employed, falling into two primary categories: participatory design activities and consultation processes (Cruickshank et al., 2013; Binder& Brandt, 2008). These approaches serve to actively engage users in the design process, thus ensuring the resulting public spaces are tailored to the community's needs and desires while simultaneously promoting transparency, accountability, and democratic governance (Hamdi & Goethert, 1997; Blomkamp, 2018).

Participatory design activities constitute a vital component of co-design methodologies, facilitating active user involvement in the design process. These activities encompass a diverse range of approaches, including community workshops, participatory design exercises, and co-design games (Botero & Hyysalo, 2013; Brandt et al., 2012).

Community workshops, for instance, serve as a foundational co-design method, assembling user groups to engage in discussions and ideation sessions that generate innovative ideas for public space design (Boyle & Harris, 2009). These workshops can adopt various formats, such as design charrettes, brainstorming sessions, and prototyping activities (Jones, 2018). Participatory design exercises represent another hands-on approach, enabling users to actively engage in the design process through activities like prototype construction, mock-up creation, and design option testing (Simonsen & Robertson, 2013). Such activities not only enhance users' understanding of the design process but also provide invaluable feedback and insights for designers (Sanders & Stappers, 2008). Furthermore, co-design games present an engaging and interactive means of involving users in the design process, utilising elements of play and exploration to gather user perspectives and ideas pertaining to public space design (Yang et al., 2021; Brandt et al., 2008; Winge & Lamm, 2019).

In addition to participatory design activities, consultation processes form another crucial aspect of co-design methodologies. These processes involve gathering information from users and other stakeholders to inform the design process through various methods, such as user surveys, focus groups, stakeholder consultation, and interviews (Blomkamp, 2018; Borgstrom & Barclay,2019). User surveys, for example, administer standardised questionnaires to collect information on user preferences and needs (Dillman et al., 2014). This data can cover a wide array of topics, ranging from user demographics to design preferences and usage patterns.

Focus groups, on the other hand, assemble small user groups to engage in discussions on specific aspects of public space design (Krueger, 2014; Hou & Rios, 2003; Kusumaningdyah & Purnamasari, 2018). These groups enable the collection of in-depth insights and feedback on particular design concepts or ideas. Stakeholder consultation processes, by contrast, involve engaging various stakeholders, such as community organisations, local businesses, and government agencies, to gather their perspectives and input on public space design (Reed, 2008; Huybrechts et al., 2017).

Lastly, interviews represent a more personalised approach to gathering information, wherein designers engage in direct conversations with users to learn about their perspectives, experiences, and needs (DiCicco-Bloom & Crabtree, 2006; Luck, 2003). The information gleaned from these interviews can be utilised to inform the design process, ensuring the resulting public spaces are responsive to the community's needs and desires.

Utilising various methods such as community workshops, participatory design exercises, focus groups, interviews and user surveys can help ensure that users' perspectives and needs are integrated into the design process. However, there are gaps in the use of these methods, such as the need for effective facilitation and organisation, adequate resources and support, and effective communication and collaboration (Eraydin, 2012; Wang et al., 2019; Kopeć et al., 2017).

New technologies, such as XR technologies, have the potential to enhance the co-design process in public spaces (Figure 4.3). XR technologies, including VR and AR, can provide designers and users with immersive and interactive experiences, allowing them to explore and test different design options in a virtual environment (Portman et al., 2015; Wolf et al., 2020). However, there is a gap in research on the use of XR technologies in co-design, and there is a need for further investigation into their potential benefits and limitations (El-Jarn & Southern, 2020; Mouratidis & Hassan, 2020).

The incorporation of the Digital Twin paradigm and Metaverse with XR technologies promises a transformative shift for co-design in public space design (Alizadehsalehi & Yitmen, 2023; Leng et al., 2022). Digital Twins, virtual replicas of physical entities, facilitate real-time simulations and comprehensive analysis, thereby strengthening data-driven decision-making (Pan & Zhang, 2023). When coupled with XR, they allow stakeholders to scrutinise and evaluate potential design impacts in a virtually realistic environment, enhancing participation (Ehab & Heath, 2023; Khan et al., 2021).

The Metaverse, envisaged as a unifying virtual space that converges virtual and physical realities, offers a continuous, immersive platform for collaborative design (Dwivedi et al., 2022). Through the utilisation of XR, co-design in the Metaverse fosters real-time collaboration among geographically diverse stakeholders (Koohang et al., 2023), facilitating more inclusive and democratic public space design (Sanchez et al., 2019; Ehab et al., 2023). The fusion of Digital Twins and the Metaverse within XR holds potential to catalyse significant innovations in co-design methodologies, leading to the creation of public spaces that are more responsive, sustainable, and attuned to user needs.

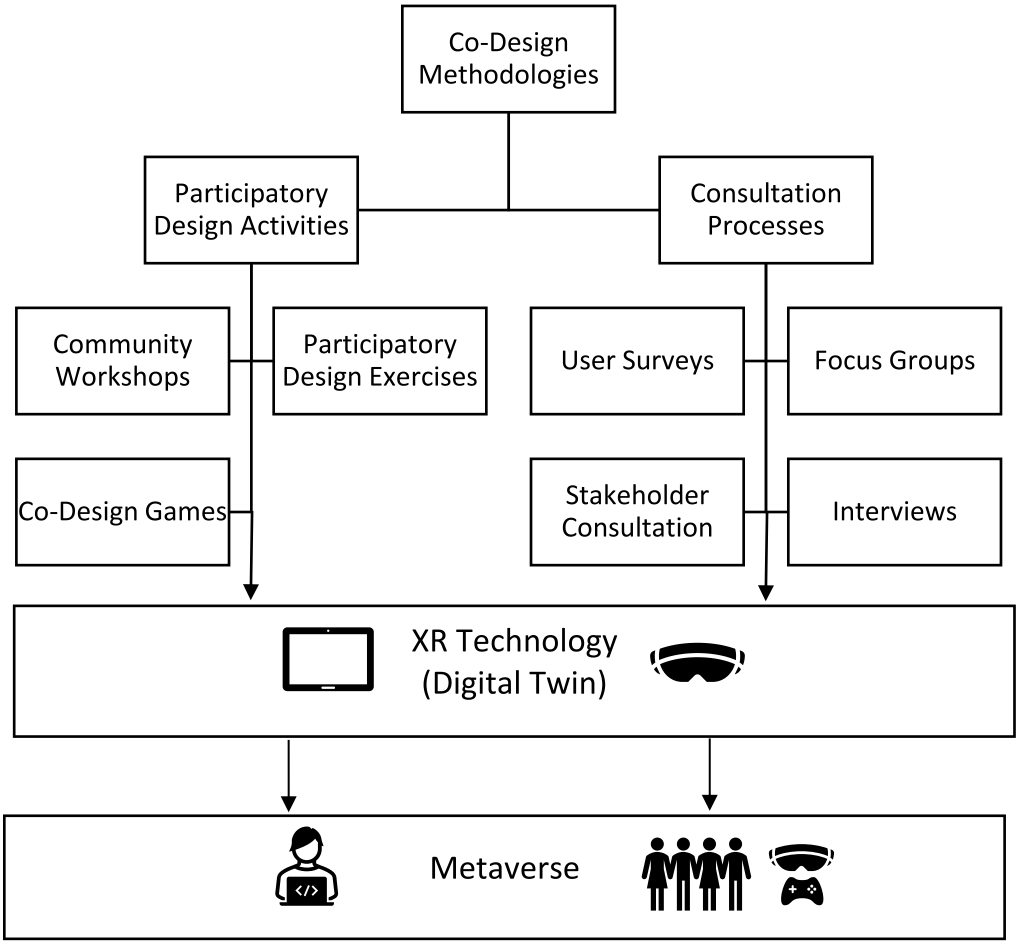


Figure 4.3: A Flowchart Illustrating the Co-Design Methodologies in Public Space Design: Participatory Design Activities and Consultation Processes (Source: Author)

In conclusion, public participation in architecture and urban projects is vital for producing spaces aligned with users' preferences. Co-design methods like community workshops and participatory exercises, foster inclusivity, accessibility, and democracy in public spaces. The evolving technology frontier, especially with XR technologies, holds promise for enriching the co-design process and the creation of more significant public spaces. Future research should investigate these technologies' merits, drawbacks, and establish guidelines for their efficacious incorporation into co-design.

4.3 XR Application in the Built Environment

The accelerated development of urbanisation worldwide presents a timely opportunity to scrutinise the effects of emerging urban design paradigms and digital transformation on urban planning (Picon, 2010). Visualising sustainable urbanism through digital technologies enables architects, urban designers, and planners to exploit the potential these technologies offer (Kolarevic, 2003). The 'virtual building' concept originated in Hungary in the late 1980s, where early microprocessors facilitated the generation of construction plans, sections, and elevations from a 3D model (Bazjanac, 2006).

Over the past 35 years, hardware and software technology advancements have transmuted the 'virtual building' concept from merely a construction process element to a medium for conveying architectural notions to the public (Eastman et al., 2011). The Architectural Engineering and Construction (AEC) sector further refined the 'virtual building' idea around the turn of the century, reconceptualising it as Building Information Modelling (BIM) (Eastman et al., 2011).

The 'Internet of Things' (IoT) integrates smart technologies, 'Cloud' storage, and fifth-generation (5G) communication to revolutionise traditional development workflows (Chettri & Bera, 2019; Chui et al., 2010). This technological revolution underscores the necessity for intelligent systems that employ IoT, artificial intelligence, and big data across various sectors (Chettri & Bera, 2019). Digital computational technologies encompass areas such as building information modelling (BIM), computational graphic imagery (CGI), virtual reality (VR), augmented reality (AR), mixed reality (MR), and artificial intelligence (AI) (Eastman et al., 2011). Consequently, extended reality (XR) offers users immersive and interactive experiences through innovative visualisations (Lindgren & Johnson-Glenberg, 2013).

XR is a collective term for three types of extended realities that utilise AI technology: virtual reality (VR), augmented reality (AR), and mixed reality (MR) (Milgram & Kishino, 1994). Each XR application has its advantages and limitations based on its capacity and interactivity features (Azuma, 1997). This chapter will specifically concentrate on VR applications in the architectural and landscaping design of elevated social spaces.

Virtual Reality (VR) employs computer-generated simulations to create virtual experiences ranging from realistic portrayals of the real world to entirely novel environments (Sutherland, 1965; Portman et al., 2015). Conventional VR systems use VR headsets or multi-projected environments to produce realistic visuals and sounds, allowing users to immerse themselves in a digital 3D environment rather than merely observing it on a traditional 2D computer screen (Sutherland, 1965; Delgado et al., 2020). The notion of virtual experiences can be traced back to the 1950s when Morton Heilig proposed an experience theatre that encompassed all senses and immersed viewers in on-screen activities (Heilig, 1962; Jones & Dawkins, 2018). Heilig even constructed a prototype called "Sensorama" and created five short films for it, engaging multiple senses, including sight, sound, smell, and touch (Pope, 2018; Heilig, 1962).

In contrast, Augmented Reality (AR) provides an interactive experience of the real-world environment enriched by computer-generated perceptual information across multiple sensory modalities (Azuma, 1997; Schmalstieg & Hollerer, 2016). AR systems merge real and virtual worlds, real-time interaction, and precise 3D registration of virtual and real objects (Billinghurst & Kato, 2002). The overlaid sensory information can be constructive (augmenting the natural environment) or destructive (masking the natural environment to display virtual objects) (Azuma, 1997; Barhorst et al., 2021). Unlike VR, AR alters the perception of the real world rather than entirely replacing the user's real-world environment with a simulated one (Carmigniani & Furht, 2011; Azuma, 1997).

Mixed Reality (MR) combines real and virtual worlds to form new environments and visualisations (Figure 4.4.) where digital and physical objects coexist and interact in real-time (Milgram & Kishino, 1994; Rokhsaritalemi et al., 2020). MR is a hybrid of real and virtual worlds and does not take place exclusively in either the physical or virtual domain (Huang et al., 2019; Milgram & Kishino, 1994). MR resembles AR but permits virtual overlay graphics to interact with the real world (Wang et al., 2008; Milgram & Kishino, 1994).

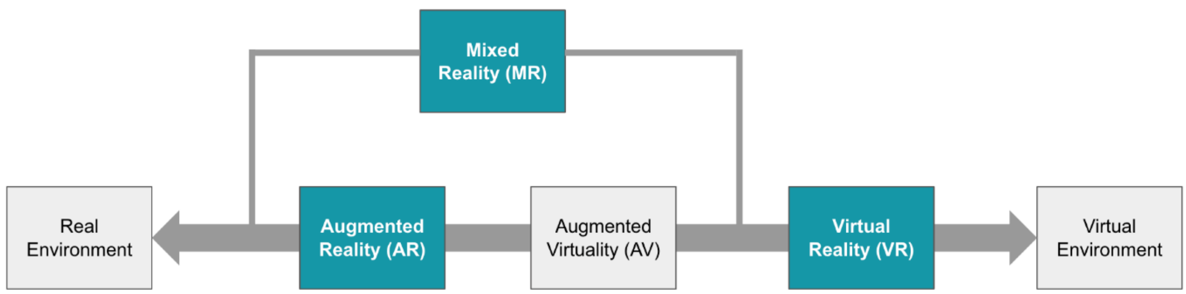


Figure 4.4: Reality–Virtuality continuum (Source: Milgram and Kishino, 1994: 3)

Incorporating Mixed Reality (MR) technology in the preliminary stages of design review and visualisation, building performance analysis optimisation, and building maintenance and operations can yield significant benefits for the Architecture, Engineering, and Construction (AEC) industry (Nee et al., 2012). MR technology fuses digital and real-world information, which is advantageous for design collaboration (Billinghurst & Kato, 2002). MR collaboration can transpire in both face-to-face and remote settings. In face-to-face MR collaboration, participants engage with the same set of virtual data information using a shared coordinate system (Billinghurst & Kato, 2002).

In remote MR collaboration, the sharing and collaboration of remote data are facilitated through the MR platform (Zaker & Coloma, 2018). Despite the potential advantages, MR collaboration has not been widely adopted in the AEC industry, and there is a particularly urgent need for applications of MR collaboration, which would enable AEC professionals to communicate and interact across distributed locations, given MR's capacity to integrate both digital and physical-world information (Jamei et al., 2017).

Virtual reality (VR) is increasingly employed in the AEC industry for design review and collaborative purposes (Yu et al., 2022). Integrating VR into the participatory process promotes engagement with end-users, streamlines feedback, and enhances understanding of design (De Siqueira et al., 2022). Immersive Virtual Environments (ImVE), such as AR and MR, offer similar benefits (Wolf et al., 2020). For instance, AR is effective in reviewing the visual elements of a building, while MR improves the spatial understanding of end-users (Saßmannshausen et al., 2021). The utilisation of immersive technologies is particularly vital to leverage the experiences of end-users who possess limited spatial comprehension and specialist knowledge and cannot effectively relate to two-dimensional drafting documents (Kim et al., 2020). BIM, which lacks the ability to involve end-users in the design process, can be efficiently combined with immersive technologies to better support end-users' decision-making processes (Alizadehsalehi et al., 2020). Collaborative VR design review benefits a wide range of disciplines involved, as it enables collaborators to interact with BIM models remotely at different stages of a building project (Ververidis et al., 2022).

In conclusion, this section offers a comprehensive overview of the concept of XR, encompassing VR, AR, and MR. The focus of the chapter is to investigate the application of VR in the built environment and urban design, particularly concerning the use of Immersive

Virtual Reality (IVR) experiences. The chapter explores how IVR can enhance the design process, convey design concepts, and involve stakeholders in a more immersive and interactive manner for the design of elevated social spaces. The chapter literature will also identify best practices, guidelines, and gaps for the use of IVR in the built environment and urban design.

4.3.1 Immersive Virtual Reality: Enhancing Human Interaction and Experience in Digital Environments

Virtual Reality (VR) has emerged as a significant research area in recent times, with the potential to transform how individuals interact with physical and informational elements (Jamei et al., 2017; Sanchez et al., 2019). The primary challenge in developing VR technologies and applications is the creation of innovative information design, storytelling, and narratives, as the full potential of this medium remains to be explored (Rubio-Tamayo et al., 2017; Bucher, 2017). This challenge transcends the technological realm, encompassing user interaction dynamics such as gameplay and novel application possibilities (Lee et al., 2021).

The concept of VR can be traced back to Weinbaum's story "Pygmalion's Spectacles" (Cruz-Neira et al., 2018; Weinbaum, 2016), where the author emphasised two fundamental VR aspects: "you are in the story" and "the story is around you." Numerous definitions of VR have emerged over the years, with some characterising it as an interactive computer simulation that senses users' positions and actions, substituting or enhancing feedback to one or more senses, thus generating a sense of mental immersion in the simulation (Cooper et al., 2018; Steuer et al., 1995). Alternatively, previous research described VR as a high-end user-computer interface involving real-time simulation across multiple sensory channels, such as visual, auditory, tactile, olfactory, and gustatory (Rubio-Tamayo et al., 2017; Sanchez et al., 2019).

In 1991, the term 'Virtual Reality' was notably absent from the Webster Collegiate Dictionary. However, just two decades later, the Collins Dictionary provided a definition for VR as a "computer-generated environment that closely resembles reality to the person experiencing it" (Collins Dictionary, 2014). VR and visualisation serve as visual aids but possess the capacity to provide more than mere visual stimulation, encompassing the experience of inhabiting a 3D world (Yu et al., 2018). Although humans primarily rely on sight for information gathering, real-world human and animal sensory experiences involve an intricate interplay of vision, hearing, balance, smell, temperature, emotion, fear, and additional factors (Fazeli, 2019).

In architecture and urban design, VR broadens the notion of 'reality,' facilitating entirely new simulations and sensations (Portman et al., 2015; Meenar & Kitson, 2020). This approach allows participants to actively engage with projects by previewing spaces, proposing modifications, and contributing to the eventual liveable environment (Alizadehsalehi et al., 2020; Van Leeuwen et al., 2018; Ehab et al., 2023). VR provides users with immersive, real-time experiences of changes and actions. While AEC professionals might be familiar with VR, the general public may still find it challenging (Zaker & Coloma, 2018; Safikhani et al., 2022).

The growing interest in media's immersive nature has prompted a more profound focus on understanding VR technology's conceptual aspects (Kitson et al., 2018). Sherman and Craig highlighted the crucial roles of design, interface, and applications in grasping VR, with its definition evolving as technology progresses (Sherman & Craig, 2018). This evolution encompasses a broader range of human factors and new environmental interaction opportunities, such as brain interfaces and their connection to VR, immersive environments, and video games (Rubio-Tamayo et al., 2017; Powers et al.,2015).

Various authors have investigated immersive environments in recent decades as the field of virtual reality has advanced. Slater and Wilbur proposed a framework for defining presence and other relevant factors in virtual environments, while Conroy attempted to characterise immersive environments by constructing experimental worlds based on physical data (Slater & Wilbur, 1997; Conroy, 2001). Kalawsky compared presence in virtual environments to presence in the physical world, considering primary sensory inputs like vision, sound, proprioception, and smell (Kalawsky, 2000).

Definitions and distinctions between virtual reality and immersive environments have been further refined in recent studies, such as those by North and North, who underscored the importance of user experiences in developing increasingly immersive applications (North & North, 2016). Cummings and Bailenson (2016) examined technological immersion's impact on presence, concluding that enhanced user-tracking, stereoscopic visuals, and broader visual display fields of view significantly affect user experience.

In architecture, immersive virtual environments (ImVE) have been widely adopted as tools for involving end-users in the participatory design process and obtaining their feedback (Safikhani et al., 2022; Meenar & Kitson, 2020). Rahimian et al. argue that VR effectively engages end-users in the design process by providing advanced visual communication and dynamic feedback initiation (Rahimian et al., 2019, 2020). ImVE has facilitated telepresence for various stakeholders, including clients, end-users, and authorities (Yu et al., 2022). However, ImVE can be intimidating for inexperienced users, particularly those outside the professional project team, as it requires various hardware and software setups (Hanson & Shelton, 2008; Ashtari et al., 2020). Despite this, the advantages of ImVE are substantial, as it can enhance the presentation of virtual models to clients, helping them better understand the design and align their business-client requirements (Yu et al., 2022; Kim et al., 2020). As a result, design professionals, such as architects, are increasingly using VR as a showcase tool for design purposes (Portman et al., 2015; Alizadehsalehi et al., 2020).

Recent advancements in design computing and cognition research have offered methodologies for studying human-human and human-agent communication and interaction in ImVE (Yu et al., 2022). Virtual collaborative design environments have been developed to improve communication, collaboration, understanding, and knowledge sharing among participants (Roupé et al.,2020; Safikhani et al., 2022). These environments have employed communication tools like text-based tools, voice chat tools, visual sharing tools, and avatars (Wen & Gheisari, 2020; Monahan et al., 2008). Research has discovered that avatar movement is effective in conveying non-verbal information, thereby enhancing collaboration efficiency.

Immersive Virtual Reality (ImVR) is an advanced form of VR that aims to provide users with a higher level of immersion by integrating additional sensory stimuli and creating a more seamless and convincing experience (Safikhani et al., 2022). ImVR often employs advanced tracking technologies, haptic feedback systems, and more sophisticated graphics and sound, fostering a stronger sense of presence in the virtual environment (Zhang et al., 2021; Rubio-Tamayo et al., 2017). This heightened immersion allows for more natural and intuitive interactions within the virtual world, ultimately leading to more meaningful engagement with the simulated environment (Meenar & Kitson, 2020; Sanchez-Sepulveda et al., 2019).

The investigation of the impact of ImVR on design perception, physiology, and cognition has led to a better understanding of how to improve design patterns, creativity, and reasoning among multiple users (Yu et al., 2022; Kim et al., 2020). Research has shown that ImVR positively affects designers' cognitive processes, including working memory, design data search and access, spatial cognition, and attention allocation, as well as users' perception (Panya et al.,2023; Rubio-Tamayo et al., 2017). ImVR has been found to enhance designers' performance, particularly in problem-finding, and to positively impact both problem and solution spaces. Moreover, collaborative design in ImVR has been shown to boost inspiration and generate new problem-solving approaches among design collaborators (Kim et al., 2020; Van Leeuwen et al., 2018).

The application of ImVR technology has been explored for its potential to enhance memory recall of information presented in multisensory VR environments (Liu et al., 2020; Yu et al., 2022). A study conducted by Harman, Brown, and Johnson compared memory recall between a VR headset and a computer monitor, finding that VR headsets improved recall performance (Harman et al., 2017). Conversely, other studies have reported conflicting evidence, suggesting that heightened immersion in VR environments may negatively affect recall. This discrepancy may be attributed to cognitive limitations and mediated arousal, which can adversely impact recall (Bailey et al., 2012; Gomez-Tone et al., 2022). The conflicting findings underscore the need for further research to examine the effects of immersive VR on participant behaviour and interaction.

4.3.2 Integration of VR Technology in Participatory Design Process of Elevated Social Spaces

The integration of VR into the participatory design of public spaces represents a transformative shift in the way urban planning, architecture, and design professionals approach their work (Jamei et al., 2017; Sanchez-Sepulveda et al., 2019). By enabling stakeholders to visualize, explore, and interact with proposed designs in an immersive virtual environment, VR can facilitate more effective communication and collaboration throughout the design process (Van Leeuwen et al., 2018; Zhang et al., 2021). This enhanced level of engagement allows for a better understanding of the spatial and design aspects of public spaces and can ultimately lead to more informed decision-making (Sanders et al., 2010; Fares et al., 2018).

One of the primary benefits of using VR in the participatory design process is its ability to foster people's perceptions of the environment (Stauskis, 2014; Webb et al., 2018). By providing users with a realistic, interactive, and immersive experience, VR can help bridge the ga between abstract concepts and tangible spaces (De Siqueira et al., 2022). This heightened level of engagement can lead to more informed feedback from the public and stakeholders, as they are better able to understand and assess the potential impacts of design choices on the overall experience of the space (Sanders & Stappers, 2008; Meenar & Kiston, 2020).

Furthermore, the use of VR can encourage a more inclusive design process by making it accessible to a broader range of participants (Stelzle et al., 2017; Kim et al., 2020). For example, individuals with mobility limitations may have difficulty attending traditional design workshops or site visits. However, through the use of VR, these individuals can participate remotely, allowing them to contribute their unique perspectives and needs to the design process (Götzelmann & Kreimeier, 2020).

A key aspect of the participatory design process is engaging a diverse range of public and stakeholders in the decision-making process (De Lange & De Waal, 2017; Bannon & Ehn, 2012). VR can play a pivotal role in facilitating this engagement by providing stakeholders and public with a more intuitive and accessible way to visualize and interact with proposed designs (Fainstein, 2014; Van Leeuwen et al., 2018). For example, VR can be used to create virtual walkthroughs of proposed spaces, allowing stakeholders to experience the space from a first-person perspective and provide feedback on the design (Wolf et al., 2020). Moreover, the use of VR can also help to democratize the design process by making it more accessible to non-experts (Roupé, 2013; Roupé et al., 2020). Traditional design tools, such as 2D plans and renderings, can be difficult for non-professionals to interpret and understand. In contrast, the immersive and interactive nature of VR makes it easier for individuals with little or no design background to engage with the design process, ultimately leading to more diverse and inclusive outcomes (Jamei et al., 2017; Yu et al., 2022).

Elevated social spaces represent a unique and increasingly relevant typology within the realm of public space design (Cho et al., 2015; Oldfield, 2019). As urban areas grapple with issues such as land scarcity, population density, and the need for more sustainable development, the design of elevated social spaces offers the potential to create additional public areas that foster social interaction and enhance urban liveability (Hadi et al., 2018; Samant & Hsi-En, 2017). By leveraging the capabilities of VR, designers can better understand the unique challenges and opportunities presented by elevated social spaces and develop innovative solutions to address these issues. The immersive nature of VR enables designers to simulate the experience of being in an elevated social space, allowing them to better understand the unique spatial qualities, views, and environmental conditions associated with these environments. Additionally, the use of VR can help identify potential issues related to accessibility, circulation, and safety, and test design interventions that address these concerns.

Despite the numerous benefits associated with the integration of VR in the participatory design of public spaces, there remain several challenges and areas for future research. One such challenge is the need to develop more intuitive and user-friendly tools and interfaces that allow users to interact with virtual environments in a natural and seamless manner (Jamei et al., 2017; Van Leeuwen et al., 2018). Additionally, there is a need to better understand the social and psychological implications of using VR in the design process, particularly in terms of how it may impact users' perceptions of space and their sense of ownership over the design outcomes (Rubio-Tamayo et al., 2017; Portman et al., 2015).

Another area of concern is the potential for digital exclusion, as not all individuals may have access to the necessary technology or the skills to effectively participate in a VR-based design process (Nabatchi et al., 2015; Wates, 2014). To address this issue, future research could explore strategies for making VR technology more accessible and affordable, as well as developing educational programs and resources to help bridge the digital divide (Schrom-Feiertag et al., 2020; Meenar & Kitson, 2020). Moreover, as VR technology continues to evolve, there is a need for ongoing research to evaluate the effectiveness of various VR tools and techniques in the context of participatory design (Yu et al., 2018; Fazeli et al., 2019). This could involve the development of standardized evaluation methodologies, as well as the establishment of best practices for integrating VR into the design process (Yu et al., 2022; Slater et al., 2020). Furthermore, interdisciplinary collaboration between urban planners, architects, designers, and VR developers will be essential in driving innovation and ensuring that VR technology is effectively harnessed to support participatory design goals (Zhang et al., 2021; Panya et al., 2023).

In conclusion, the integration of virtual reality in the participatory design of public spaces, particularly elevated social spaces, presents a significant opportunity to enhance collaboration, foster people's perceptions, and ultimately, improve the quality of urban environments. While some studies have explored the use of VR technology in architecture and urban design (Zaker & Coloma, 2018; Kim et al., 2020), there remains a dearth of academic literature that evaluates the effectiveness of VR technology as a tool for co-designing public spaces with specific focus on elevated social spaces (Sidani et al., 2021; Chettri & Bera, 2019). To address this gap, it is imperative to conduct further research that investigates the ways in which individuals interact and behave in virtual environments compared to real environments, assesses the validity of VR technology as a tool for co-designing public spaces, and evaluates its impact on the quality of designs and levels of user satisfaction (Huang et al., 2019; Alizadehsalehi & Yitmen, 2021). The current lack of research in this area presents a valuable opportunity for academic inquiry, which can deepen our understanding of the potential of VR technology to enhance public participation in the design process and to create more efficient, resilient, sustainable, and equitable elevated social spaces.

4.4 VR Hardware and Software tools

In recent scholarly works, Manis and Choi delineated three fundamental components of virtual reality (VR): content, experience, and hardware. According to their definition, VR content constitutes an environment that emulates a sense of presence in either the real world or an imagined one (Manis & Choi, 2019). Typically, this content is represented through lifelike images or videos in a 360-degree or 3D digital depiction of a real environment (Ritter III & Chambers, 2022; Martínez-Navarro et al., 2019).

Within the domain of virtual reality experiences in architecture and urban design, a range of distinct types has emerged to cater to diverse applications and user requirements. The 360-degree video format, for instance, involves pre-recorded footage obtained using a 360-degree camera. This format affords users a panoramic view of their surroundings, enabling them to examine the environment from any angle, albeit without the ability to interact or navigate within the space (Mouratidis & Hassan, 2020; Yu et al., 2018). A comparable format, the 360-degree rendering, yields a similar experience but relies on computer-generated imagery instead of real-world footage. Frequently utilised in architectural and design settings, these renderings create static, photorealistic visualisations of spaces, allowing users to inspect their environment but not engage with or traverse it (Chen, 1995; Pham et al., 2018).

A more advanced format, known as the interactive VR experience, provides users with the opportunity to explore and interact with the virtual environment in real-time. Through this format, users can teleport or navigate using controllers, manipulate objects, and engage with dynamic elements embedded in the environment (Kersten et al., 2018). Such interactive VR experiences find widespread applications in gaming, training simulations, and architectural walkthroughs, presenting users with a fully immersive and captivating experience (Safikhani et al., 2022; Bozzelli et al., 2019).

While the 360-degree format is more cost-effective, it lacks the interactivity and immersiveness of other formats. It depends on videos or images of real situations captured by 360-degree cameras or rendered in 360 views, consequently impacting the user's VR experience (Wen & Gheisari, 2021; David et al., 2022). On the other hand, the interactive 3D format is digitally crafted using an array of computer vision software (Martínez-Navarro et al., 2019). This research will concentrate on the interactive VR 3D digital tool, which boasts a higher level of immersion, high-fidelity models, and superior visualisation and rendering capabilities for representing the built environment and designing elevated social spaces.

An assortment of tools and applications currently available on the market possess the capability to create an immersive experience in a digital environment. These applications and software warrant further investigation in terms of their reliability for use in architecture and urban design, with the aim of fostering public perceptions and addressing the need for designing public spaces and democratising decision-making.

As defined by Manis and Choi (2019) and Berg and Vance (2017), VR hardware pertains to the equipment that allows users to interact with, view, and experience VR content. As previously discussed, the core component of VR hardware is a head-mounted display (HMD). Many contemporary HMDs feature stereoscopic displays, tracking systems, and a wide field of vision. Incorporating gyroscopes and accelerometers, these devices can identify the user's position and adjust the scene accordingly (Greengard, 2019; Yaqoob et al., 2020). Supplementary accessories for HMDs may encompass haptic systems such as data gloves with tracking sensors, which facilitate interaction (Gallace, 2022; Yin et al., 2021).

4.4.1 VR Hardware Tools

The technology of VR has evolved rapidly, resulting in the development of various hardware tools and types of VR headsets. These headsets can be broadly categorized based on their connection types: PC-based, standalone, and Mobile-based devices (Huang et al., 2019). This section aims to provide an overview of these VR headsets, as well as a comparison of their features and functionalities. In addition to connection types, another crucial aspect of VR headsets is their tracking system, which determines how accurately the device can capture the user's movement and orientation in the virtual environment (Caserman et al., 2019; Huang et al., 2019). There are two main types of tracking systems used in VR headsets: external tracking, which relies on base stations placed around the user's physical space, and inside-out tracking, which uses embedded cameras on the headset itself to track the user's movement (Angelov et al., 2020; Khundam et al., 2021).

Another important aspect of VR headsets is the degrees of freedom (DOF) they offer. Degrees of freedom refer to the number of independent ways a user can move or rotate in the virtual environment (Huang et al., 2019). There are two primary levels of DOF in VR headsets: 3 DOF and 6 DOF. 3 DOF systems are limited to tracking the user's rotation around the three perpendicular axes, which are pitch, yaw, and roll (Rossi et al., 2021). 6 DOF systems, on the other hand, track both the user's rotation around the three axes and their movement along those axes. This allows for a more realistic and immersive experience, as users can move freely within the virtual environment (Huang et al., 2019; Rossi et al., 2021).

1- PC-based VR Headsets

PC-based VR headsets represent a significant portion of the virtual reality market, catering to users who seek high-quality, immersive experiences (Evans, 2018). These headsets rely on a connection to a capable personal computer (PC) through cables, which provide the necessary processing power and graphical capabilities to render complex virtual environments (Huang et al., 2019). As a result, PC-based VR headsets generally offer superior visual fidelity and performance compared to standalone or mobile-based devices, at the expense of reduced portability and increased setup complexity (Huang et al., 2019).

The tracking capabilities of PC-based VR headsets have evolved over time, with the introduction of both first- and second-generation devices. First-generation VR devices, such as the Oculus Rift and HTC Vive, along with newer high-end devices like the HTC Vive Pro, Pimax 5K/8K, and Valve Index, rely on separate base stations for tracking (Huang et al., 2019; Mealy, 2018). These external sensors, often referred to as 'outside-in' tracking systems, detect the user's movement within a predefined area and provide accurate 6 DOF (Degrees of Freedom) tracking for both position and rotation (Mealy, 2018; Shin & Lee, 2022).

In contrast, second-generation PC-based VR headsets, such as the Oculus Rift S, HTC Vive Cosmos, and various Windows Mixed Reality VR headsets, employ an inside-out tracking approach through embedded cameras (Al-Jundi & Tanbour, 2022). This eliminates the need for separate base stations and simplifies the setup process, while still maintaining 6 DOF tracking capabilities. The inside-out tracking technology utilises advanced computer vision algorithms to analyse the headset's surroundings and track the user's movement within the virtual environment (Aukstakalnis, 2016).

In summary, PC-based VR headsets cater to users who demand high-quality, immersive virtual reality experiences, often for professional or enthusiast applications (Evans, 2018). These devices leverage the processing power and graphical capabilities of connected PCs to deliver superior performance, with varying tracking methodologies across first- and second-generation devices (Huang et al., 2019). The consistent support for 6 DOF tracking across all PC-based VR headsets ensures that users can fully engage with and explore virtual environments, making these devices a popular choice for individuals seeking the most immersive VR experiences available (Shen et al., 2020).

2- Standalone VR Headsets

Standalone VR headsets have gained considerable attention in the field of virtual reality due to their inherent advantages in terms of convenience and portability (Lee et al., 2021). These devices are characterised by their self-contained nature, eliminating the need for an external computing device such as a PC or a smartphone (Casini, 2022). The embedded hardware and processing capabilities within the headset enable users to engage in immersive virtual experiences without the constraints of being tethered to a stationary device (Aukstakalnis, 2016). This freedom of movement contributes to the growing popularity of standalone VR headsets, as it addresses one of the major limitations of earlier generations of VR technology (Evans, 2018).

The tracking capabilities of standalone VR headsets are a critical aspect of their overall performance and user experience (Al-Jundi & Tanbour, 2022). Most of these devices employ an inside-out tracking approach, which involves the use of embedded cameras and advanced computer vision algorithms to support 6 DOF tracking (Aukstakalnis, 2016). This enables the headset to accurately capture the user's position and rotation within the virtual environment without the need for external base stations or additional tracking equipment (Al-Jundi & Tanbour, 2022). Standalone VR headsets, such as the Oculus Quest, HTC Vive Focus, and Lenovo Mirage Solo, have successfully integrated this technology to offer users a more immersive and interactive virtual experience (Johnson-Glenberg, 2018). However, it is worth noting that some lower-end standalone VR devices, such as the Oculus Go, are limited to 3 DOF tracking, which restricts the user's movement to rotation only, resulting in a less immersive experience (Mealy, 2018).

3- Mobile-based VR Headsets

Mobile-based VR headsets represent an accessible entry point into the world of virtual reality, catering primarily to users who seek a cost-effective and convenient solution for basic VR experiences (Evans, 2018). These headsets function as a housing for VR lenses and are designed to be compatible with a wide range of smartphones (Mealy, 2018). The processing power, display, and sensors of the smartphone are leveraged to generate the virtual environment, which means that the performance and capabilities of mobile-based VR headsets are heavily dependent on the specifications of the associated smartphone (Aukstakalnis, 2016).

The tracking capabilities of mobile-based VR headsets are generally limited to 3 DOF, which means that users can only rotate around the three perpendicular axes (pitch, yaw, and roll) without the ability to move along those axes within the virtual environment (Mealy, 2018). This restriction is primarily due to the reliance on smartphone sensors and the absence of embedded cameras or external tracking equipment (Al-Jundi & Tanbour, 2022). Examples of mobile-based VR headsets include the Samsung Gear VR, Google Daydream View, and various generic VR headsets that are compatible with a wide array of smartphones (Evans, 2018).

Whilst mobile-based VR headsets may not offer the same level of immersion and interactivity as their PC-based or standalone counterparts with 6 DOF support (Lee et al., 2021), they serve an important role in making virtual reality accessible to a broader audience (Pellas et al., 2021). By providing a more affordable and readily available entry point into VR, these headsets can help familiarise users with the technology and pave the way for the adoption of more advanced systems in the future (Eswaran & Bahubalendruni, 2022).

In the following (Table 4.1.), a comparison between various VR and MR headsets is provided, summarizing their connection types, tracking capabilities, and other relevant features.

Table 4.1.: Comparison between various VR and MR headsets (Source: Author)

Headset	**Type**	**Connection**	**Tracking**	**DOF**	**Picture**
Oculus Rift	VR	PC-based	Base stations	6	
HTC Vive/Pro/Eye	VR	PC-based	Base stations	6	
Pimax 5K/8K	VR	PC-based	Base stations	6	
Valve Index	VR	PC-based	Base stations	6	
Oculus Rift S	VR	PC-based	Inside-out	6	
HTC Vive Cosmos	VR	PC-based	Inside-out	6	

WMR VR headsets	VR	PC-based	Inside-out	6	
Oculus Quest	VR	Standalone	Inside-out	6	
Oculus Quest 2	VR	Standalone	Inside-out	6	
Meta Quest Pro	MR	Standalone	Inside-out	6	
HTC Vive Focus/Plus	VR	Standalone	Inside-out	6	
Lenovo Mirage Solo	VR	Standalone	Inside-out	6	
Microsoft HoloLens 1 & 2	MR	Standalone	Inside-out	6	
Magic Leap One	MR	Standalone	Inside-out	6	

Lenovo ThinkReality A6	MR	Standalone	Inside-out	6	
Oculus Go	VR	Standalone	-	3	
Samsung Gear VR	VR	Mobile phone-based	-	3	
Google Daydream View	VR	Mobile phone-based	-	3	
Generic VR headsets	VR	Mobile phone-based	-	3	

4.4.2 VR Software and Applications

This section delves into the diverse array of VR software and applications utilised in architecture and urban design, with an emphasis on their compatibility and key features. The VR solutions discussed in this section can be classified into three primary categories. Firstly, standalone VR applications function autonomously and furnish immersive design capabilities without necessitating additional software. Secondly, gaming engines and platforms proffer potent tools for crafting interactive and visually captivating environments, frequently employed in tandem with architectural modelling software. Lastly, VR plugins for architectural modelling software augment the functionality of existing design tools, incorporating VR capabilities and streamlining the design process.

In the subsequent Table 4.2, a comprehensive comparison of these VR software and plugins is presented, delineating their type, compatible software, and features. By scrutinising the various offerings within each category, professionals and researchers can attain a profound understanding of the current landscape of VR tools in the field of architecture and urban design. Additionally, this examination enables the identification of the most appropriate solutions for specific needs and objectives.

Table 4.2.: Comparison of VR software and plugins for architecture and urban design (Source: Author)

#	Name	Type	Compatible Software	Features
1	Arkio	VR Standalone Application	Revit, Rhino	Immersive VR environment, real-time design modifications, absence of texture support, multi-user collaboration, 3D modelling, and presentation capabilities in virtual reality.
2	Fuzor	VR Standalone Application	Revit, Rhino	Synchronized live updates, integration of various disciplines within a virtual reality environment, clash detection, 4D simulations, and BIM data visualization.
3	Gravity Sketch	VR Standalone Application	Rhino	Virtual reality support, real-time editing, absence of texture support, multi-user functionality, 3D sketching and modelling in immersive environments, and export capabilities in OBJ, IGES, and FBX formats.
4	Holodeck Nvidia	VR Standalone Application	3Ds Max, Maya	NVIDIA Iray rendering technology, compatibility with standard NVIDIA vMaterials, high-quality visualization in virtual reality, limited connectivity with Omniverse, and AI-enhanced graphics.
5	TwinMotion	VR Standalone Application	Revit, Rhino, SketchUp, ArchiCAD, Cinema 4D	Compatibility with virtual reality, real-time visualization, dynamic weather system, landscape and vegetation tools, import and export capabilities for 3D models, and efficient design exploration.
6	VU.CITY	VR Standalone Application	Rhino, Revit, SketchUp, AutoCAD	3D city modelling, urban planning and analysis tools, interactive visualization,

				virtual reality support, integration with BIM data, and scenario-based planning.
7	IrisVR—The Wild	VR Standalone Application	Rhino, Revit, Navisworks, SketchUp	Support for multiple users, 3D model viewing and annotation within virtual reality, real-time collaboration, and visualization of BIM data.
8	Enscape	VR Plugin	Revit, SketchUp, Rhino, ArchiCAD, Vectorworks	Photorealistic rendering, interactive virtual reality environment, real-time walkthroughs, material and lighting adjustments, and efficient communication among stakeholders.
9	Mindesk	VR Plugin	Rhino, Revit, Solidworks, Unreal Engine	Absence of web interface and database support, real-time virtual reality modelling, seamless CAD integration, and streamlined design workflows.
10	Tridify	VR Plugin	Revit, ArchiCAD, Tekla Structures	BIM data visualization, virtual reality support, web-based platform, interactive 3D models, and collaboration tools.
11	SENTIO VR	VR Plugin	SketchUp, Revit, Rhino	Virtual reality support, immersive presentations, 360-degree rendering, real-time collaboration, and integration with various design software.
12	Autodesk Revit Live	VR Plugin	Revit	Interactive visualization, virtual reality support, real-time design modifications, integration with BIM data, and streamlined collaboration among stakeholders.
13	SketchUp VR	VR Plugin	SketchUp	Virtual reality support, real-time design modifications, integration with SketchUp models, navigation and presentation tools, and compatibility with various virtual reality headsets.
14	Unity	Game Engine	FBX, OBJ, 3ds Max, Maya, Blender	Real-time rendering, support for virtual and augmented reality, 2D and 3D visualization, comprehensive asset library, scripting capabilities, integration with BIM tools, and customizable design workflows.
15	Unreal Engine	Game Engine	FBX, OBJ, 3ds Max, Maya,	Real-time rendering, virtual and augmented reality support, high-quality

			Blender, SketchUp, Revit	visualization, integration with BIM tools, Datasmith import, interactive experiences, and advanced material and lighting adjustments.
16	CryEngine	Game Engine	FBX, OBJ, 3ds Max, Maya, Blender	High-quality rendering, support for virtual reality, real-time lighting and reflections, large-scale terrain tools, and integration with architectural visualization tools.
17	Godot Engine	Game Engine	FBX, OBJ, Blender, Collada	2D and 3D visualization, virtual and augmented reality support, scripting capabilities, customizable workflows, and integration with 3D modelling software.
18	Mozilla Hubs	VR Standalone Chat Platform	GlTF, FBX, OBJ	Browser-based virtual reality platform, real-time collaboration, 3D model importing, avatars, customizable spaces, and cross-platform compatibility.
19	Any Land	VR Standalone Chat Platform	N/A	Virtual reality chat platform, in-world creation tools, user-generated content, customization, and interactive environments.
20	VRChat	VR Standalone Chat Platform	Unity, Blender, FBX, OBJ	Virtual reality chat platform, user-generated content, avatars, interactive worlds, and integration with Unity for custom content creation.

4.5. Gamification in Architecture and Urban Design: The Role of Unreal Engine in Virtual Reality Integration

Gamification in architecture and urban design involves incorporating game design elements and principles into non-game contexts, such as architectural planning, urban development, and design visualization (Deterding et al., 2011; Münster et al., 2017). The objective of gamification is to increase user engagement, promote collaboration, and facilitate a deeper understanding of spatial relationships and design aesthetics (Hamari et al., 2014). By introducing game-like experiences to the design process, professionals can achieve a more interactive, immersive, and dynamic approach, allowing users to explore and experience the design before its realization (Alizadehsalehi et al., 2021; Deterding, 2019).

To implement gamification in architecture and urban design, specific tools and software are required. Two of the most popular and widely-used platforms are Unreal Engine and Unity (Fonseca et al., 2017; Kharvari & Kaiser, 2022). Both game engines are highly versatile and capable of creating realistic, interactive 3D environments suitable for architectural visualization and urban planning applications (Safikhani et al., 2022; Hakak et al., 2019). Unreal Engine, developed by Epic Games, is known for its high-quality graphics and powerful real-time rendering capabilities. Unity, on the other hand, is a more accessible platform, often favoured by smaller developers for its ease of use and extensive asset library (Kavouras et al., 2023; Šmíd, 2017). Both engines support VR integration, making them ideal for gamification projects in architecture and urban design (Fonseca et al., 2021).

Unreal Engine stands out as a powerful tool for creating interactive VR design platforms in architecture and urban design. Its robust real-time rendering capabilities, combined with an extensive library of assets and visual effects, enable designers to create highly realistic and immersive environments (Kavouras et al., 2023; David et al., 2022). This level of detail allows users to navigate and interact with virtual spaces, providing invaluable insights into the design's functionality, aesthetics, and overall impact (Fonseca et al., 2017; Shannon, 2017).

Using Unreal Engine's Blueprints system, architects and urban planners can develop customized interactions, allowing users to modify elements within the virtual environment (Kavouras et al., 2023; Calvo et al., 2018). This feature promotes collaboration and encourages public participation in the design process, bridging the gap between designers and end-users (Deterding et al., 2011). Furthermore, the engine's built-in physics simulation capabilities can facilitate the exploration of structural performance and environmental factors, enabling architects to make informed design decisions (De Amicis et al., 2019; Fonseca et al., 2021). Unreal Engine's compatibility with various VR headsets and devices further enhances the immersive experience (Hakak et al., 2019). By integrating VR with gamification principles, architects and urban designers can better communicate their ideas, test design alternatives, and receive valuable feedback from users (Sanchez-Sepulveda et al., 2019; Deterding, 2019). This synergy can lead to more sustainable, functional, and aesthetically pleasing designs that cater to the needs and preferences of the community (Hamari et al., 2014).

Several real-world applications demonstrate the potential of gamification in architecture and urban design using Unreal Engine as a VR design platform (Calvo et al., 2018; Kavouras et al., 2023). For instance, urban planners have used the engine to develop interactive master plans, enabling stakeholders and community members to explore and provide feedback on proposed developments (Kavouras et al., 2023; Kitchin et al., 2021). Architects have also employed the engine to create virtual walkthroughs of building designs, allowing clients and end-users to experience the space before construction begins (Fonseca et al., 2017). Additionally, educational institutions have embraced gamification and VR to enhance architectural education (Fonseca et al., 2021). Using tools like Unreal Engine, students can engage in interactive design exercises and simulations, improving their spatial understanding and design skills (Fonseca et al., 2017; Valls et al., 2016). These applications underscore the potential of gamification and VR in architecture and urban design.

Despite the promising potential of gamification in architecture and urban design, several challenges and limitations warrant further investigation (Deterding, 2019). Research on the practical applications and implications of gamification in VR, particularly using Unreal Engine, is still limited (Kavouras et al., 2023; Münster et al., 2017). Factors such as the validity and legitimacy of information obtained from VR simulations, potential biases in the application of technology, and the need for user accessibility and inclusivity must be considered (Fonseca et al., 2021; Sanchez-Sepulveda et al., 2019). Moreover, the steep learning curve associated with mastering game engines like Unreal Engine may pose a barrier for some professionals (Hakak et al., 2019; Šmíd, 2017). Therefore, ongoing efforts to improve the usability and accessibility of these tools are crucial (Fonseca et al., 2021; Calvo et al., 2018). Additionally, the development of standardized methods and protocols for integrating gamification and VR in architectural and urban design processes will help ensure consistency and reliability across different projects (Deterding, 2019; Kitchin et al., 2021).

Furthermore, ethical considerations must be addressed when using gamification and VR in architecture and urban design (Hamari et al., 2014). Issues such as data privacy, consent, and potential manipulation of user experiences need to be carefully examined to maintain trust and transparency between designers and users (Deterding, 2019; De Amicis et al., 2019). Future research should also explore the potential of integrating other emerging technologies, such as artificial intelligence (AI), with gamification and VR to further enhance the design process (Hakak et al., 2019; Kharvari & Kaiser, 2022). For example, AI-driven algorithms can be used to analyze user interactions within virtual environments, providing valuable insights into design preferences and patterns (Gao & Li, 2022; Cavalcanti et al., 2021).

In summary, gamification in architecture and urban design, integrated with VR, offers a novel approach to enhancing user experience, collaboration, and understanding of spatial design. Tools such as Unreal Engine and Unity provide the necessary capabilities to create interactive, immersive environments, with Unreal Engine emerging as a powerful platform for developing interactive VR design platforms. The successful implementation of gamification in architecture and urban design depends on overcoming the associated challenges and limitations while exploring new technological synergies. By addressing these issues, the field can unlock the full potential of gamification and VR, leading to more sustainable, functional, and aesthetically pleasing designs that cater to the needs and preferences of diverse communities.

4.6. Integrating VR to BIM

Building Information Modelling (BIM) constitutes a model-centric approach that fosters collaboration among professionals within the Architecture, Engineering, and Construction (AEC) sectors, facilitating a more streamlined design, construction, and operation of built infrastructure (Abbasnejad et al., 2021; Noghabaei et al., 2020). BIM empowers architects to generate three-dimensional representations that encompass data pertaining to the physical and functional characteristics of edifices, thereby enriching the design process and offering improved comprehension of building operation and maintenance. The concept of 'interoperability' denotes the premise that all stakeholders engaged in the construction process utilise the same model (Pany et al., 2023; Zaker & Colma, 2018).

Nonetheless, despite BIM's potential to effectuate a transformative impact on the architectural domain, extant literature suggests that its full capabilities have not yet been exploited. Barriers in communication among design team members and clients have been identified as significant impediments to the realisation of BIM's optimal level of interoperability (Alizadehsalehi et al.,2020; Liu et al., 2019). Consequently, it is imperative to address these communication challenges and devise strategies to enhance collaboration within the AEC community, thereby unlocking BIM's potential to revolutionise the way buildings are designed, constructed, and maintained. The integration of VR with BIM offers a novel approach to overcoming these limitations, enabling immersive and interactive design experiences that facilitate collaboration, improve communication, and promote stakeholder engagement (Ververidis et al., 2022).

The combination of BIM and VR technologies presents numerous advantages for architecture and urban design projects. By incorporating VR into the BIM process, architects can generate immersive and realistic visualizations of their designs, allowing stakeholders to experience and navigate virtual spaces before construction begins (Sidani et al., 2021). This not only enhances the understanding of spatial relationships and design aesthetics but also fosters collaboration among professionals and stakeholders by providing a shared, interactive environment for design exploration and feedback (Bernstein, 2018).

Various VR plugins have been developed to integrate VR functionality within BIM systems, such as Enscape, Twinmotion, and Autodesk Live. These plugins enable real-time rendering of BIM models, allowing users to navigate and interact with virtual environments using a range of VR devices, including headsets and controllers (Davidson et al., 2020). This immersive experience promotes active engagement and facilitates a more intuitive understanding of design proposals, enhancing decision-making and collaboration throughout the design process (Huang et al., 2019).

Despite the potential benefits, integrating BIM and VR also presents certain challenges that must be addressed to optimize the process. One such challenge is the technical complexity of combining these technologies, which may pose a barrier for some professionals (Chettri & Bera, 2019). Additionally, concerns regarding the validity and accuracy of data obtained from VR simulations, as well as the potential for biased user experiences, must be considered to ensure that the technology is used effectively and responsibly (Zhang et al., 2020).

The development of VR plugins for BIM systems has been instrumental in facilitating the integration of these technologies in architectural and urban design processes (Sidani et al., 2021). These plugins enable architects to generate immersive and interactive visualizations of their BIM models, allowing stakeholders to experience and navigate virtual spaces before construction begins.

Enscape is an emerging VR plugin for BIM, showing potential for enhanced visualisation capabilities and supporting real-time rendering of BIM models (Baghalzadeh

Shishehgarkhaneh et al., 2022). With its seamless integration into popular BIM software such as Autodesk Revit , ArchiCAD, and SketchUp, Enscape has the ability to enable architects and designers to quickly generate immersive, high-quality virtual environments directly from their BIM data (Gao & Li, 2022). This streamlined workflow has the potential to reduce the need for time-consuming export and import processes, allowing project teams to iterate rapidly and respond to stakeholder feedback more effectively (Schiavi et al., 2022).

Although Enscape shows promise as a valuable tool for architectural visualisation, its potential for creating interactive participatory models and fostering meaningful engagement remains an area of ongoing research (Ververidis et al., 2022). The current limitations of user interaction in Enscape, such as the lack of real-time collaboration features and tools for manipulating design elements within the virtual environment, highlight the need for further investigation into optimising its implementation in participatory design processes (Sidani et al., 2021). This is particularly relevant in the context of stakeholder involvement and collaboration, where enabling users to actively engage with and modify design proposals can lead to more inclusive, responsive, and ultimately successful outcomes (Liu et al., 2019).

4.6.1 Integrating AI with BIM and VR

Artificial Intelligence (AI) constitutes a rapidly advancing domain that incorporates sophisticated computational methodologies, empowering machines to mimic human-like cognitive abilities through learning, reasoning, and adaptation (Pan & Zhang, 2021; Shabbir & Anwer, 2018). In the realm of architecture and urban design, AI holds the potential to transform conventional workflows, augment decision-making procedures, and bolster community participation (Wu et al., 2010; Jha et al.,2021). By capitalizing on AI, professionals in architecture and urban design can process extensive data volumes, discern patterns, and generate optimized design alternatives based on specific constraints and requirements. This empowers practitioners to examine a wider array of design options, facilitating more informed decisions that ultimately benefit communities and stakeholders (Sönmez, 2018; Yigitcanlar et al., 2021).

Text-to-image prompts serve as textual guidelines or directives that instruct AI-driven platforms to create visual representations (Beyan & Rossy, 2023). Within architectural and urban design contexts, these prompts enable professionals, clients, and stakeholders to effectively communicate design ideas, requirements, and preferences by describing desired attributes, characteristics, or spatial relationships in natural language (Wu et al., 2022). When incorporated into AI-driven platforms, these textual prompts generate a variety of design alternatives and visualizations that align with the described concepts, fostering a more intuitive and interactive design process (Lavdas et al., 2023).

Utilizing text-to-image prompts in architectural and urban design offers numerous advantages, including enhanced communication, increased collaboration, and the exploration of a more extensive range of design alternatives (Yigitcanlar et al., 2021). By offering a more accessible and engaging approach for users to articulate their design ideas, text-to-image prompts can facilitate more effective communication and collaboration among professionals, clients, and stakeholders throughout the design process (Beyan & Rossy, 2023). Additionally, by producing visual representations based on textual inputs, AI-driven platforms enable users to explore a multitude of design alternatives, ultimately leading to more informed decision-making and superior outcomes for communities and stakeholders (Wu et al., 2022).

Various platforms have been developed for text-to-image synthesis, each employing distinct approaches and techniques (Beyan & Rossy, 2023). Some notable platforms include Midjourney, DALLE, and Stable Diffusion. Midjourney, an AI-driven platform, leverages a combination of machine learning algorithms and natural language processing to create visual representations based on textual inputs, enabling users to rapidly and effortlessly generate detailed architectural and urban design concepts by describing desired features and characteristics (Lavdas et al., 2023). DALLE, developed by OpenAI, is a deep learning-based model capable of producing high-quality images from textual descriptions, permitting users to create and explore a broad range of design alternatives in a more immersive and interactive manner (Watson et al., 2023). Stable Diffusion, another AI-driven platform, utilizes advanced machine learning techniques to generate detailed and realistic visual representations based on textual inputs, presenting novel opportunities for architectural and urban design exploration and communication (Beyan & Rossy, 2023).

Computational design methods encompass the application of algorithms, simulations, and digital tools to create and optimize architectural and urban design solutions, which includes various fields such as parametric design, digital fabrication, and BIM (Caetano et al., 2020). By incorporating AI into computational design methods, professionals can further enhance their design workflows, allowing them to examine a more comprehensive range of design alternatives and make well-informed decisions (Pena et al., 2021). AI-driven computational design tools can analyze intricate datasets, detect patterns, and generate optimized design solutions based on specific constraints and requirements (Baduge et al., 2022).

Integrating AI with BIM can yield significant benefits for architectural and urban design processes (Pan & Zhang, 2023). By embedding AI-driven tools within BIM workflows, professionals can exploit the data-rich nature of BIM models to refine design solutions, promote collaboration, and facilitate communication among stakeholders (Alizadehsalehi et al., 2020). For instance, Revit, a widely-used BIM software, can be augmented with AI-driven plugins such as VERAS that offer intelligent design suggestions based on user prompts (Evolve Lab, 2023). These prompts operate as text-to-image inputs, enabling users to describe desired modifications or features, which are then visually translated by the AI. By harnessing the power of AI, these plugins dynamically adapt designs captured from Revit, allowing users to swiftly explore various design alternatives and achieve more efficient and inclusive design solutions (Gao & Li, 2022).

The integration of AI with BIM and VR holds transformative potential for community engagement in architecture and urban design (Zhang et al., 2020; Bussell et al., 2023). VERAS, an innovative AI-driven plugin for Autodesk Revit, revolutionizes the design process by intelligently suggesting design modifications based on user prompts (Evolve Lab, 2023). These prompts function as text-to-image inputs, allowing users to describe desired changes or features, which are then translated into visual design alterations by the AI. By harnessing the power of AI, VERAS dynamically adapts the design captured from Revit and Enscape, enabling users to rapidly explore various design alternatives. By leveraging the synergies between BIM, VR, and AI, professionals can foster iterative design exploration and enhance community involvement and creativity (Darko et al., 2020; Ehab et al., 2023). Nevertheless, further investigation is required to develop interactive design models that effectively capture users' and clients' needs, ultimately leading to more efficient and inclusive design solutions in architecture and urban design (Baghalzadeh Shishehgarkhaneh et al., 2022).

While the integration of AI, BIM, and VR technologies offers significant benefits for architectural and urban design processes, several challenges and limitations must be addressed to fully realize their potential (Kozlovska et al., 2021). These challenges include the need for improved interoperability among different platforms and software tools, the development of standardized protocols for data exchange and communication, and the identification and mitigation of potential biases in AI-driven design solutions (Jia et al., 2019). Moreover, further research is needed to explore the practical applications and implications of integrating AI, BIM, and VR technologies in architectural and urban design processes (Chettri & Bera, 2019). This research should focus on the development of a novel innovative framework and methods that can effectively capture user behaviour and preferences, as well as the assessment of the potential impact of these technologies on the overall quality and sustainability of design solutions (Gan et al., 2020).

In conclusion, the integration of AI, BIM, and VR technologies offers promising opportunities to revolutionize architectural and urban design processes by fostering more effective communication, collaboration, and decision-making among professionals, clients, and stakeholders. By addressing the challenges and limitations associated with these technologies and conducting further research on their practical applications and implications, the architecture and urban design industries can harness their transformative potential to create more efficient, inclusive, and sustainable design solutions for the benefit of communities and stakeholders alike.

4.7 Chapter Summary

This chapter delivers an exhaustive exploration of the central research objectives, mainly focusing on the application and assessment of Virtual Reality (VR) as a co-design interactive tool for designing elevated resilient social spaces. It highlights the gaps in current research, particularly concerning the use of immersive VR to capture and understand user behaviour and perceptions related to the design and activities within these spaces.

Initiating the discourse, the chapter examines VR as a powerful tool for analysing human interactions within designed spaces. It gives an overview of the diverse VR tools, applications, and software currently available, outlining the gaps, opportunities, and challenges in applying VR for urban and elevated public space design.

A key part of the chapter is dedicated to the role of community participation in the design of public spaces, emphasising the criticality of public involvement in the process. It discusses co-design workshops as an effective means of engaging local stakeholders and accentuates the value of co-design in creating inclusive and responsive elevated social spaces that cater to community needs and aspirations.

The chapter then delves into the various co-design methodologies, participatory design activities, and consultation processes. The importance of integrating these methods to ensure user perspectives are incorporated in the design process is emphasised. Moreover, it explores the potential of Extended Reality (XR) technologies, such as VR and Augmented Reality (AR), in enhancing the co-design process, underscoring the need for additional research to comprehend their benefits and limitations. Additionally, the chapter investigates the applications of VR in the built environment, discussing the evolution of virtual building concepts and the recent advancements in hardware and software technology. The potential benefits of immersive VR experiences in design review, collaborative design, and user engagement are highlighted, with a focus on integrating Building Information Modeling (BIM) with immersive technologies and collaborative VR design review.

The chapter also explores the integration of gamification, VR, BIM, and Artificial Intelligence (AI) in architecture and urban design processes, comparing two interactive VR systems: one based on gamification methods and the other integrating VR into BIM software. The capabilities of these systems, powered by AI tools, are discussed, and the challenges and limitations of implementing gamification in architecture and urban design are acknowledged.

This chapter sets out to illuminate three primary research objectives of the thesis. The first objective is to test the use of Virtual Reality (VR) as a co-design interactive tool for the design of elevated resilient social spaces. The second objective involves highlighting and addressing the research gap in using immersive VR to capture users' behaviour and perception about the design and activities of the space. This necessitates a comparative study between behaviours exhibited in the physical and the virtual world. The third objective is to test interactive design tools and simulations for public engagement with the design process. A critical gap identified here is the lack of intuitive systems and software that architects and urban designers can effectively utilize. To bridge this gap, the thesis proposes the design and testing of two interactive VR systems: one employing gamification methods, and the other integrating VR into Building Information Modelling (BIM) software. These systems will be evaluated for their capabilities and potential enhancement through Artificial Intelligence (AI) tools. Through these objectives, the chapter aims to provide a comprehensive exploration of VR as a co-design tool, thereby contributing to bridging the existing gaps in knowledge in the field of architecture and urban design.

In conclusion, Chapter 4 serves as a comprehensive literature review, providing insights into the use of co-design methods and XR technologies, specifically VR, in urban design and elevated public space design. It emphasizes the importance of public participation, highlights the benefits and challenges of co-design, and explores the potential of XR in enhancing the design process. The chapter calls for further research to uncover the best practices, guidelines, and gaps in utilizing XR, particularly immersive VR experiences, in the built environment and urban design.

4.8.In-depth Conclusion and Detailed Elucidation of Research Gaps

Drawing Chapter 4 to a conclusion necessitates a thorough examination of the expansive literature discussed in Chapters 3 and 4. This body of work, which investigates the complex nature of the resilient design of elevated social spaces, acts as both a foundational framework and a guiding mechanism. It provides a comprehensive insight into the prevailing academic milieu, while simultaneously highlighting the regions yet to be navigated. Such uncharted areas, identified as research gaps, are pivotal in determining the direction of this study, guiding it towards novel frontiers promising academic advancement.

The Covid-19 pandemic has profoundly altered the urban landscape, precipitating significant shifts in urban design and planning. Though existing literature offers an overview of these changes, there remains a discernible absence of in-depth examination into the nuanced impacts of the pandemic on the design, functionality, and stewardship of elevated social spaces, particularly in London. This research seeks to bridge this knowledge gap. By scrutinising visitor behaviours, circulation patterns, and activities across three distinct periods - pre-pandemic, intra-pandemic, and post-pandemic - this study endeavours to provide an exhaustive insight into the evolving design principles and management strategies governing these unique urban realms.

The existing literature, while offering a broad perspective on elevated social spaces, lacks an intricate academic analysis of their diverse typologies, notably the distinction between design paradigms such as Sky Gardens and elevated parks. This research intends to address this omission through a meticulous comparative examination. The aim is not merely to identify prevailing design models but to probe their underlying principles, highlight their unique attributes, and grasp the detailed nuances distinguishing one typology from another. In doing so, this study aspires to provide a thorough taxonomy, draw insights from various design approaches and case studies, and establish guidelines to enhance adaptability and social resilience within these spaces, particularly in the context of London.

The co-design framework, which underscores the symbiotic collaboration between the public, stakeholders, and designers, emerges as a pioneering paradigm in contemporary design discourses. Yet, prevailing literature discernibly lacks comprehensive empirical substantiation and pragmatic elucidation of this concept. This deficit prompts the research enquiry: *How do the benefits and challenges of employing VR in architectural and urban design manifest in the context of elevated social spaces in London?* This research is poised to undertake both validation and refinement of the co-design approach, with a particular emphasis on the transformative capacities of interactive VR modalities. Core objectives include the authentication of a model delineating VR's impact on public space design and a thorough examination of user behaviour within immersive VR contexts.

Whilst the academic realm has begun to acknowledge the transformative potential of VR in architectural and urban design, there remains an evident void concerning the evolution and critical assessment of intuitive VR platforms and software. This lacuna prompts the salient research enquiry: *To what extent can VR methodologies be efficaciously employed to solicit feedback from the wider community and vested stakeholders concerning the innovative design of elevated social spaces?* This study aspires to critically assess avant-garde VR platforms, honing in on their functional efficacy and versatile adaptability. The ultimate ambition lies in the formulation of a comprehensive design framework for elevated social spaces in London, one that synergistically melds VR technologies with profound community engagement. This endeavour will entail a rigorous evaluation of two emergent systems: a gamification-driven paradigm harnessing the vitality of game mechanics, and an advanced BIM VR platform. The investigative journey promises insights into the operational efficiency, versatility, and transformative potential of these platforms in re-engineering public participation and design methodologies.

In light of the identified gaps and the revisited research questions, this study endeavours to forge a pivotal contribution to the scholarly dialogue surrounding elevated social spaces. Marrying theoretical acumen with empirical observations, the research seeks to establish a resilient and foundational edifice for ensuing academicians and professionals. The ultimate aspiration is to ensure that the design and stewardship of these spaces embody sustainability and resilience.

Chapter 5: Methodology and Research Design

5.1 Introduction

The objective of this chapter is to elucidate the methodologies utilised in gathering primary data for this research project. The chapter begins with an exploration of the philosophical underpinnings of the research, followed by a comprehensive overview of the research methods employed. Furthermore, an extensive discussion and justification of the approaches adopted in each research phase are provided.

The initial section presents the research methods employed, focusing on the use of online data gathering through surveys and social media platform analysis. The purpose of this is to provide a macro perspective on the application of various interactive VR design platforms for facilitating an immersive design experience in the context of elevated social spaces in London.

The following section introduces the phenomenal qualitative method, employing a participatory action research approach, as the primary method used in this study (Table 5.1). The first investigation examines the cognitive and physical experiences of visitors engaging with elevated social spaces pre-, mid-, and post-pandemic. This investigation predominantly utilises direct observations and walk-along interviews with garden visitors. The second investigation focuses on an immersive interactive design experience for the selected case studies, employing an interactive VR experiment complemented by semi-structured interviews with participants. This approach enables an in-depth exploration of VR technology's impact on participants' experiences and interactions within the design of elevated social spaces in London. It further permits a comprehensive assessment of the effectiveness of the chosen methods by contrasting the similarities, differences, and limitations present in both physical and virtual environments. This comparison ultimately evaluates the integration of VR in constructing an interactive participatory design model for elevated social spaces and identifies the necessary guidelines and frameworks.

In summary, primary data collection was executed in two research phases. This chapter outlines the data collection process for each phase, encompassing instrument design, population, sampling method, and analytical technique. Lastly, considerations regarding reliability and validity, limitations, and ethical concerns related to the research design are discussed.

Table 5.1: Qualitative research paradigm primary sections covered in Chapter 5 (Source: Author)

Qualitative Research Paradigm	
Philosophical Paradigm	
Constructivist/Transformative	Knowledge is socially constructed; research should seek transformation and social justice.
Research Design	
Phenomenological:	Understanding lived experiences and perceptions of individuals.
Research Purpose	
Exploratory:	Initial phase investigating the phenomena.
Explanatory:	Later phase explaining relationships and causes in the phenomena.
Approach	
Participatory Action Research (PAR)	Emphasizes participation and action, fostering collective inquiry and experimentation grounded in the lived experience and social history of participants.
Case Studies: The Sky Garden and Crossrail Place in London	
Study 1: Physical cognitive experience	Methods: Direct observations and semi-structured interviews.
Study 2: Virtual experience	Methods: VR interactive experiments followed by semi-structured interviews.

5.2 Methodological Framework

The principal aim of this research is to explore the future potential of VR technology as a co-design approach for designing elevated social spaces employing London as a distinct case study. The study is committed to developing a comprehensive framework for the design of London's vertical public realm to enhance community engagement and participation in the design of these unique urban spaces. This framework also provides valuable insights for similar urban environments worldwide, indicating the potential wider application of the findings as a possible outcome of this research. In order to fulfil this central aim, the research is guided by two key objectives. The first objective is to identify and analyse the challenges and opportunities inherent to the design of elevated social spaces in London. The second objective is to experiment with and evaluate the effectiveness of VR as a tool for co-design and community engagement in the design process (Table 5.2 and 5.3).

This research adopts a robust methodological framework, deeply rooted in a qualitative approach and underpinned by the Participatory Action Research (PAR) model. This choice is in harmony with the interdisciplinary and dynamic nature of the study. The emphasis on a qualitative approach is instrumental in providing an enriched and nuanced understanding of the subject matter. This approach moves beyond the limits of quantitative data, probing into the subjective experiences, perceptions, and behaviours of the individuals who engage with these spaces. The depth and richness of the qualitative approach ensure a comprehensive examination of how different stakeholders perceive and interact with elevated social spaces, thus revealing insights that would otherwise remain concealed. The adoption of the Participatory Action Research (PAR) model is central to this study, facilitating a highly collaborative and inclusive method of inquiry. This model encourages active involvement from the participants, transforming them from mere subjects of study to co-researchers who play an active role in shaping the course and outcomes of the research.

The first section comprises an extensive literature review divided into three chapters, each focusing on a distinct aspect of the research subject. The first two chapters deal with the history of private-public spaces in London and the global context of elevated social spaces in the post-Covid-19 environment. The third chapter, "Immersive Virtual Reality in Urban Design: A Study of Tools and Challenges," provides a systematic review of innovative VR tools and applications in architecture and urban design, with an emphasis on their use in public and social spaces design. These three chapters create a strong theoretical foundation for the subsequent empirical investigation.

To deepen the understanding of the challenges facing London's elevated social spaces, two case studies - The Sky Garden and Crossrail Place Roof Garden - are investigated through direct observation techniques and walk-along interviews with users (Figure 5.1). These two case studies have been strategically chosen to compare different typologies and types of elevated social spaces. This approach provides a richer understanding of the user experience and design challenges across a range of elevated social spaces.

In the second section, the methodology investigates the effectiveness of VR as a co-design tool (Figure 5.1). This involves creating two interactive VR models using two distinct methodologies: one employs a game engine (Unreal Engine) to model the Sky Garden, and the other utilizes Building Information Modelling (BIM) software (Revit and Enscape) for Crossrail Place Roof Garden. These differing approaches allow the research to compare the efficacy and potential challenges of game engine-driven VR (which typically excels in creating more immersive and interactive environments) versus BIM-based VR (which often provides a more realistic and accurate representation of the physical world). Participants engage with these models in interactive VR experiments, and semi-structured interviews are conducted to gather insights on the challenges, potential, and limitations of using VR as a co-design tool.

The final section synthesizes the insights derived from the real-world and VR studies. It provides a comparative analysis of users' experiences in both the physical and virtual environments, thereby assessing the effectiveness of VR as a co-design tool. The outcome of this comparative analysis informs the development of a comprehensive design framework for London's vertical public realm, thereby promoting community engagement and participation in the design of elevated social spaces.

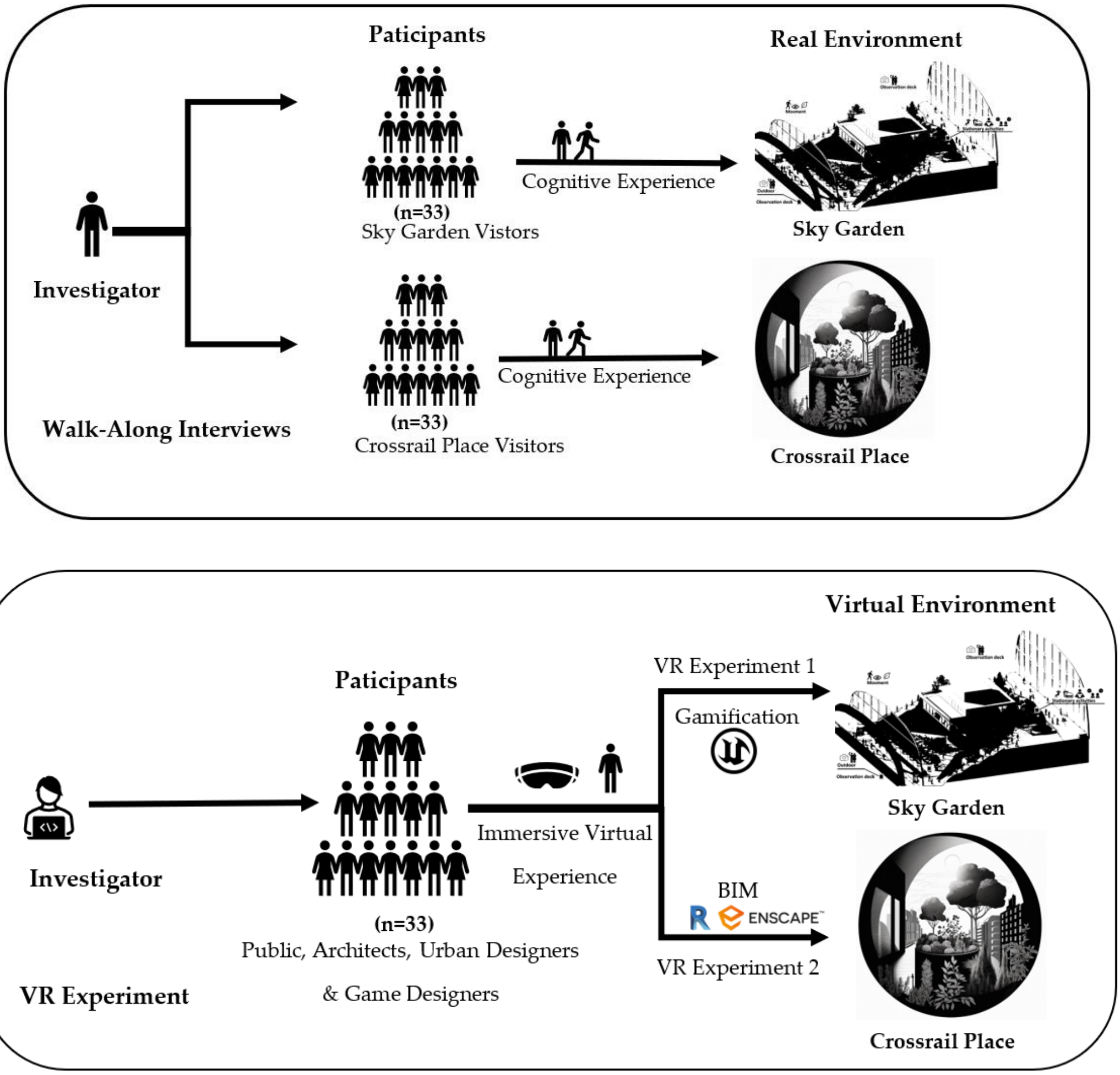


Figure 5.1: Methodological framework demonstrates the methods used in the walk-along interview in the cognitive physical study and the VR experiments in the virtual study (Source: Author)

Table 5.2: Mapping of Research Objectives to Utilised Methods (Source: Author)

Research Objectives	**Methodology**				
	Literature Review	Cognitive Physical Experience		Virtual Experience	
		Direct Observations & Depthmap X	Walk along Interviews	VR Experiments	Semi-structured Interviews
To identify the design qualities and factors affecting the design of elevated social spaces and providing a guideline for the adaptability and the social resilience of vertical urban spaces.					
To observe and study visitors' behaviour, circulation and activities before, during and post-pandemic in two different typologies of elevated social spaces.					
To validate and test a proposed model portraying the influence of an interactive VR experience for the Co-design of elevated social spaces.					
To develop a framework for the design of elevated social spaces in London that considers VR technologies and community engagement.					

Table 5.3: Mapping of Research Questions to Utilised Methods (Source: Author)

Research Questions	**Methodology**				
	Literature Review	Cognitive Physical Experience		Virtual Experience	
		Direct Observations & Depthmap X	Walk along Interviews	VR Experiments	Semi-structured Interviews
How do various challenges and factors impact the design of elevated social spaces in London?					
How has Covid-19 pandemic impacted upon the design and management of elevated social spaces in London?					
What are the benefits and challenges of using VR in architecture and urban design for the design of elevated social spaces in London?					
How can VR technology be utilised to gather feedback from the community and stakeholders on the proposed design of elevated social spaces?					

5.3 Research Philosophy

A comprehensive understanding of the methodology employed in this PhD thesis necessitates a thorough examination of the research philosophy, which serves as the foundation of the study (Creswell & Poth, 2016). Research philosophy pertains to the set of beliefs and assumptions that inform the development of a research strategy, shaping the selection of research methods and methodologies (Bryman, 2016). It encompasses a philosophical paradigm, a conceptual framework providing a systematic and coherent approach to understanding the nature of reality, knowledge, and the researcher's role within the research process (Guba & Lincoln, 1994).

The researcher's philosophical stance is integral in determining the research approach, as it embodies their ontological and epistemological beliefs (Crotty, 1998). Ontology concerns the nature of reality and the essence of the phenomena under investigation, while epistemology addresses the nature, sources, and limitations of knowledge, as well as the processes through which it can be acquired and validated (Blaikie, 2007).

Within the domain of social sciences, the primary research philosophies include positivism, interpretivism, realism (or critical realism), and pragmatism (Morgan, 2014). Each of these philosophical orientations possesses distinct ontological and epistemological assumptions that underpin the research strategy, methods, and methodology (Creswell, 2013; Padilla-Díaz, 2015).

1. Positivism: Positivism advocates that knowledge is solely derived from empirical observations and quantifiable data (Hume, 2007). This philosophy adheres to a deterministic and objective view of reality, frequently employing quantitative methods to test hypotheses and establish generalisable laws that govern the observed phenomena.
2. Interpretivism: In contrast to positivism, interpretivism underscores the significance of comprehending the subjective meanings and interpretations that individuals ascribe to their experiences (Schutz, 1967). This philosophical perspective acknowledges the intricacy and context-dependence of social phenomena, often

employing qualitative methods to examine and interpret participants' viewpoints and experiences (Geertz, 1973).

3. Realism (or critical realism): Realism contends that reality exists independently of human perceptions, yet acknowledges that our understanding of reality is inevitably influenced by social, cultural, and historical factors (Bhaskar, 2013). Realists endeavour to uncover the underlying structures and mechanisms responsible for generating observed phenomena, often employing a combination of quantitative and qualitative methods to achieve a more nuanced understanding.
4. Pragmatism: Pragmatism is predicated on the practical implications and utility of research, emphasising the importance of selecting methods and approaches best suited to addressing the research question (Morgan, 2014). Pragmatists often adopt a pluralistic approach, amalgamating elements of positivism, interpretivism, and realism as necessary to accomplish their research objectives.

The research philosophy employed in this study is informed by the ontological and epistemological assumptions that underpin the research strategy, methods, and methodology (Creswell, 2013). By acknowledging and articulating these assumptions, the researcher can ensure a coherent and consistent approach to the study, thereby enhancing its rigour, credibility, and academic merit (Lincoln & Guba, 1985). The chosen philosophical stance plays an essential role in providing a solid foundation for the subsequent methodological decisions and the overall integrity of the research endeavour (Bryman, 2016).

5.3.1 Ontology, Epistemology, and Methodology

In the realm of social sciences, the research process is deeply rooted in the researcher's ontological, epistemological, and methodological perspectives. These three interconnected dimensions inform the development and execution of research projects, providing a philosophical and methodical foundation for understanding the phenomena under investigation (Corbetta, 2003; Della Porta & Keating, 2008).

Ontology refers to the researcher's system of beliefs concerning the nature of reality, which in turn, influences the choice of research subject and shapes the manner in which the subject is perceived and studied (Saunders et al., 2009). There are two primary ontological perspectives: objectivism and subjectivism. Objectivism posits that social entities exist as meaningful realities external to the social actors concerned with their existence (Crotty, 1998; Saunders et al., 2009). In contrast, subjectivism assumes that social phenomena are continually constructed and revised by the perceptions and actions of the relevant social actors (Saunders et al., 2009; Bahari, 2010).

Epistemology, the theory of knowledge, addresses the possibilities, nature, sources, and limitations of knowledge in a given field (Dudovskiy, 2016; Blaikie, 1991). It provides a philosophical grounding for determining the types of knowledge possible and the criteria for judging their adequacy and legitimacy (Blaikie, 2004). The understanding of knowledge and its acquisition influences the research questions, methodology, and methods that a researcher deems appropriate for addressing the research questions (Hammond & Wellington, 2020). Ontology and epistemology thus hold paramount importance in shaping the research project (Hammond & Wellington, 2020).

Methodology encompasses the techniques and instruments employed to acquire knowledge (Corbetta, 2003). It is independent of ontological and epistemological questions and addresses how methods are employed in the research process (Della Porta & Keating, 2008). Methodology is inherently linked to the researcher's epistemological stance and theoretical framework, as it dictates the methods used for data collection and analysis.

In summary, the interplay between ontology, epistemology, and methodology is vital in guiding the research process. Ontology shapes the researcher's understanding of reality, while epistemology provides a foundation for determining the types of knowledge possible and the criteria for their legitimacy. Methodology, in turn, outlines the techniques and instruments used to acquire knowledge. By acknowledging and articulating these dimensions, researchers can develop a coherent and robust research strategy, ensuring the academic rigour and credibility of their findings.

5.3.2. Philosophical Paradigm: Constructivist/Transformative

The constructivist/transformative paradigm is the philosophical cornerstone of this study, guiding the approach and methods employed. This paradigm posits that reality is socially constructed and subject to transformation based on individual experiences and societal changes (Mertens, 2007). The complexity and fluidity of phenomena under study, namely resilient design for elevated social spaces and the use of virtual reality for community engagement, align with this paradigm (Creswell, 2013).

Constructivism and Research Methods

In line with the constructivist belief, this research recognizes the diverse and subjective nature of human experiences and perceptions, particularly in relation to their interactions with elevated social spaces in London (Denzin & Lincoln, 2011; Denzin, 2018). The methods employed—direct observations, semi-structured interviews, and a virtual reality experiment—provide avenues for understanding these subjective experiences and perceptions.

Direct observations enable the researchers to understand the context and dynamics of the interaction between individuals and their environment, capturing the lived reality as it unfolds (Angrosino, 2007).

Semi-structured interviews, on the other hand, allow for deeper exploration of participants' perceptions, feelings, and thoughts regarding their experiences in the elevated social spaces. By allowing participants to share their narratives, this method aligns well with the constructivist view of multiple realities (Brinkmann, 2013).

Virtual reality experiments also play a crucial role in this research. These experiments provide participants with an immersive experience of the designed elevated social spaces, enabling them to directly interact with these spaces and to provide valuable feedback. The virtual reality setting allows the study to go beyond static observation and incorporate dynamic participation, thus supporting the transformative aspect of the research paradigm (Steed et al., 2016; Sanchez-Sepulveda et al., 2019).

Transformative Aspect of the Study

The transformative dimension of the paradigm is realized through the application of the research findings to improve the design and utility of elevated social spaces. By giving voice to community members and allowing them to participate actively in the research process, the study also addresses social justice concerns, a key element of the transformative paradigm (Mertens, 2007; 2010). Thus, the research not only uncovers the subjective realities associated with the design of elevated social spaces, but it also contributes towards transforming these spaces to better serve the needs and preferences of their users.

In summary, by employing a constructivist/transformative paradigm, this research acknowledges the subjective nature of human experiences, values the perspectives of its participants, and aims to generate knowledge that can facilitate positive transformation in the design of elevated social spaces in London.

5.3.3 Research Purpose: The Roles of Exploratory and Explanatory Research

In accordance with Saunders et al. (2009), the intent of a study can be divided into exploratory, descriptive, explanatory, or evaluative categories. This study adopts a blend of exploratory and explanatory research (Holmström et al., 2009) in order to comprehensively address the topic of resilient design for London's elevated social spaces.

The first phase of the study is exploratory in nature, seeking to delve into the relatively uncharted territory of resilient design in London's elevated social spaces and the application of interactive virtual reality co-design approaches for community engagement (Sandelowski & Barroso, 2003). Exploratory research is primarily concerned with uncovering new insights, unveiling patterns, and understanding phenomena in areas previously unexamined. The ever-evolving field of urban design, particularly with the integration of innovative technologies such as virtual reality, embodies this fluidity and justifies the adoption of an exploratory approach.

Building upon the foundation laid by the exploratory phase, the second phase of the study takes an explanatory approach (Biecek & Burzykowski, 2021). Explanatory research is geared towards providing clarity and further explanation to findings obtained from the exploratory research (Guetterman et al., 2015). It endeavours to elaborate on the "why" behind observed patterns or behaviours and is typically employed following an initial exploratory investigation.

In this research, the explanatory phase aims to delve deeper into the insights gathered from the exploratory stage, providing a more precise understanding of the challenges and opportunities inherent in resilient design for elevated social spaces in London, and the potential for harnessing virtual reality co-design approaches for community engagement. Although it's possible to conduct research with a single-focused purpose, this study acknowledges the value in adopting a dual approach—utilising both exploratory and explanatory purposes—to provide a more comprehensive understanding of the topic at hand

(Saunders et al., 2009). The exploratory phase sets the stage by offering initial insights into the field, while the explanatory phase further refines these insights, enhancing the depth and accuracy of the study's findings. Ultimately, this combination of approaches, strengthens the overall aim of the research and enables a more rigorous investigation into the complex phenomena of resilient design for elevated social spaces.

5.4 Phenomenological Qualitative Method

The phenomenological qualitative method is a research approach that seeks to explore and understand the lived experiences of individuals and the meanings they ascribe to these experiences (Butina et al., 2015). This method is grounded in phenomenology, a philosophical perspective that emphasizes the study of consciousness and the subjective aspects of human experiences (Pollio et al., 1997). Phenomenology seeks to understand the essence of a phenomenon as it is experienced by individuals in their unique contexts, revealing the complexities and nuances of their subjective realities (Van Manen, 2023).

Phenomenological qualitative research is particularly well-suited for studies that aim to gain a deeper understanding of human experiences, emotions, beliefs, and perceptions, which may not be easily quantifiable or generalizable (Tomkins & Eatough, 2013). The phenomenological qualitative method is most appropriate in situations where the research question requires a deep exploration of human experiences and the meanings individuals ascribe to them (Knudsen et al., 2012). This method is particularly useful when the researcher seeks to uncover the essence of an experience, rather than simply describing or quantifying it (Willis et al., 2016).By focusing on the subjective perspectives and experiences of individuals, phenomenological research can provide valuable insights into the complexities of human behavior and emotions that may not be captured through quantitative or other qualitative methods (Miller et al., 2018).

There are several compelling reasons to employ the phenomenological qualitative method in a research study:

Depth of understanding: Phenomenological research offers a level of depth and detail that is difficult to achieve with quantitative methods or other qualitative approaches (Matua & Van Der Wal, 2015). By focusing on individuals' lived experiences and subjective interpretations, the researcher can gain a more profound understanding of the phenomenon under investigation.

Context sensitivity: Phenomenological research acknowledges the importance of context in shaping individuals' experiences and perceptions (Tuffour, 2017). This method allows the researcher to explore the complex interplay of personal, social, cultural, and environmental factors that contribute to the participants' unique perspectives.

Emphasis on meaning: Phenomenology is concerned with understanding the meanings that individuals assign to their experiences (Selinger & Crease, 2002). By delving into the participants' interpretations and beliefs, the researcher can uncover the underlying values, assumptions, and worldviews that shape their perspectives and experiences.

Flexibility: The phenomenological qualitative method is flexible and adaptable, allowing the researcher to respond to the unique needs and characteristics of the study population (Tomkins & Eatough, 2013). This flexibility can enhance the relevance and applicability of the research findings, particularly in situations where standardized measures or predetermined categories may not adequately capture the participants' experiences.

The phenomenological qualitative method is particularly well-suited for research in the social science field of architecture and urban design, given its focus on human experiences and perceptions (Van Manen, 2023). The following are the key advantages of employing this method in such a research context:

1. In-depth understanding of human experiences: The phenomenological approach provides researchers with a deeper and more nuanced understanding of how individuals experience and perceive architectural and urban design elements, compared to quantitative methods or other qualitative approaches (Knudsen et al., 2012). This emphasis on lived experiences and subjective interpretations allows researchers to explore the complex relationships between people and their built environments, leading to valuable insights and knowledge in the field.
2. Sensitivity to cultural and social context: Phenomenological research recognizes the importance of context, encompassing social and cultural factors, in shaping individuals' experiences and perceptions of architecture and urban design (Tuffour, 2017). This method enables researchers to investigate the intricate interplay of

personal, social, cultural, and environmental factors that contribute to participants' unique perspectives, facilitating a more comprehensive understanding of the complex nature of human interactions within the built environment.

3. Focus on meaning-making in architectural and urban design: Phenomenology is concerned with understanding the meanings individuals ascribe to their experiences within architectural and urban spaces (Selinger & Crease, 2002). Through examining participants' interpretations and beliefs, researchers can uncover the underlying values, assumptions, and worldviews that shape their perspectives and experiences, thereby enriching the understanding of the impact of architectural and urban design on people's lives.
4. Adaptability and flexibility in research design: The phenomenological qualitative method offers adaptability and flexibility, allowing researchers to tailor their approach to the specific needs and characteristics of the study population (Tomkins & Eatough, 2013). This flexibility enhances the relevance and applicability of research findings, particularly in situations where standardized measures or predetermined categories may not adequately capture the nuances of participants' experiences with architecture and urban design (Willis et al., 2016).

5.4.1 Implementing a Phenomenological Research Design in Architecture and Urban Design Studies

Phenomenological research design is an inductive and interpretive approach that emphasizes the subjective experiences and perceptions of participants within the context of the phenomenon under investigation (Pollio et al., 1997). By employing a phenomenological research design, researchers can uncover the meanings and interpretations that individuals ascribe to their experiences, which can contribute to a deeper understanding of the subject matter (Tomkins & Eatough, 2013). In order to maintain focus on the phenomenon of interest, the researcher initiates the study with a clearly defined research question that encapsulates the essence of the experiences to be explored (Butina et al., 2015). Various elements contribute to the construction of a comprehensive phenomenological research design (Flood, 2010).

Participant selection is a crucial aspect of phenomenological research, as the individuals involved must be capable of providing rich and relevant information about the phenomenon under investigation (Butina et al., 2015). Purposeful sampling is employed to recruit individuals who have directly experienced the phenomenon since their insights can contribute significantly to understanding the subject matter (Knudsen et al., 2012). Two common strategies for purposeful sampling include criterion-based sampling and snowball sampling (Cypress, 2015). Criterion-based sampling involves selecting participants based on predetermined criteria relevant to the research question (Tuffour, 2017), while snowball sampling involves identifying initial participants who meet the selection criteria and then asking them to recommend or refer other individuals with similar experiences (Cypress, 2015).

In phenomenological studies, small sample sizes are typical, facilitating in-depth exploration of participants' experiences (Cypress, 2015). Determining the appropriate sample size for a phenomenological study is guided by the concept of saturation, which is reached when no new themes or insights emerge from the data (Knudsen et al., 2012). Researchers should be attentive to the emergence of new themes and insights during data collection and analysis, continuing to recruit participants until saturation is achieved (Miller et al., 2018).

Ethical considerations are paramount when conducting a phenomenological study, as researchers engage with participants' personal experiences and perspectives, which may encompass sensitive or confidential information (Butina et al., 2015). Researchers must obtain informed consent from participants, ensuring that they understand the purpose of the study, the voluntary nature of their participation, and the confidentiality measures in place to protect their privacy (Flood, 2010). Additionally, researchers should implement measures to maintain confidentiality and anonymity and respect participants' autonomy and their right to withdraw from the study at any time without consequence (Cypress, 2015).

Data collection in phenomenological research typically involves in-depth, semi-structured interviews that allow the researcher to explore participants' perspectives in a flexible and open-ended manner (Knudsen et al., 2012). To ensure a comprehensive understanding of the phenomenon, researchers may employ additional data collection methods such as participant observation, written reflections, and visual data (Hayllar & Griffin, 2005; Loder, 2014). Participant observation involves the researcher observing and participating in the everyday activities and experiences of the participants, providing a firsthand account of the context in which the phenomenon occurs (Seamon, 2000). Written reflections may include participants' journal entries or autobiographical narratives, offering additional insights into their perspectives and the meanings they attribute to the phenomenon (Willis et al., 2016). Visual data, such as photographs or drawings, can provide alternative ways for participants to express their experiences and contribute to a richer understanding of the phenomenon under investigation (Loder, 2014).

5.5 Participatory Action Research

Participatory Action Research (PAR) is a collaborative research methodology that engages stakeholders throughout the research process, fostering a sense of ownership and empowerment (Chevalier & Buckles, 2019). It is rooted in social constructivist epistemology and emphasizes the co-construction of knowledge through critical reflection, dialogue, and collective action (Glassman & Erdem, 2014). By involving participants in the identification of issues, data collection, and analysis, this approach democratizes the research process and enhances validity by drawing on the lived experiences and perspectives of those directly affected (Dworski-Riggs & Langhout, 2010). Consequently, PAR serves as a powerful tool in addressing complex social issues and promoting transformative change, aligning with the emancipatory goals of critical social science (Howard & Somerville, 2014).

The origins of PAR can be traced back to the works of Kurt Lewin, Paulo Freire, and Orlando Fals Borda, who sought to challenge traditional top-down research approaches and give voice to marginalized communities (Borda, 2006). Over the years, PAR has been applied across various disciplines and contexts, including education, public health, community development, and environmental justice (James et al., 2007).

One of the fundamental tenets of PAR is democratic participation, which encourages the active involvement of stakeholders, including researchers, participants, and communities, in every aspect of the research process (Ozer et al., 2010). This collaboration ensures that the research outcomes are relevant, valid, and meaningful to the people involved. Furthermore, PAR recognizes knowledge as socially constructed, and therefore, the process of knowledge creation is a collective endeavor (Glassman & Erdem, 2014). Researchers and participants engage in ongoing dialogue, reflection, and negotiation to co-create knowledge that reflects their diverse perspectives and experiences (Chevalier & Buckles, 2019).

Reflexivity is another core principle of PAR, as it requires researchers to engage in continuous self-examination and reflection on their own values, beliefs, and biases, and how these may influence the research process (Chevalier & Buckles, 2019). This reflexivity fosters transparency and enables researchers to navigate the complex power dynamics inherent in the research process. Moreover, PAR goes beyond knowledge production to foster positive change in individuals, communities, and institutions (Dworski-Riggs & Langhout, 2010). This change may manifest as shifts in awareness, attitudes, behaviors, policies, or practices that promote social justice, equity, and sustainability (Howard & Somerville, 2014).

The PAR process typically unfolds through iterative cycles of reflection, planning, action, and evaluation (Chevalier & Buckles, 2019). During the problem identification stage, researchers and participants collaboratively identify the research questions or issues to be addressed. This stage involves a process of dialogue and critical reflection, as participants share their experiences, perceptions, and concerns, and collectively prioritize the issues that matter most to them (Katoppo & Sudradjat, 2015). Subsequently, researchers and participants collaboratively develop a plan for data collection and analysis that is responsive to the identified issues and that builds on the strengths, resources, and capacities of the community (James et al., 2007).

Data collection methods in PAR can be diverse, including interviews, focus groups, surveys, observations, or participatory mapping (Katoppo & Sudradjat, 2015). Researchers and participants work together to collect data, with participants taking on various roles, such as co-researchers, interviewers, or facilitators, depending on their interests, skills, and capacities (Ozer et al., 2010). During the data analysis stage, researchers and participants engage in a collaborative process, using techniques such as thematic analysis, content analysis, or participatory data analysis workshops (James et al., 2007). This process involves the identification of patterns, themes, or trends in the data that shed light on the research questions or issues (Chevalier & Buckles, 2019).

Interpretation and reflection occur as researchers and participants collaboratively interpret the findings of the data analysis, linking these findings to the broader context and literature, and critically reflecting on their implications for action and change (Glassman & Erdem, 2014). Based on the findings and reflections, researchers and participants collaboratively develop strategies for action that address the identified issues and promote positive change (Ozer et al., 2010). These strategies may range from individual-level interventions to community-based initiatives or advocacy efforts (Katoppo & Sudradjat, 2015).

The advantages of PAR include the democratization of the research process, the enhancement of research validity through the inclusion of diverse perspectives, and the potential for transformative change (Chevalier & Buckles, 2019). However, it also has limitations, such as the potential for power imbalances between researchers and participants, the time-consuming nature of the process, and potential difficulties in achieving consensus among stakeholders (Dworski-Riggs & Langhout, 2010).

One of the challenges in PAR is navigating power imbalances between researchers and participants, which may arise due to differences in education, expertise, or social status (Dworski-Riggs & Langhout, 2010). To mitigate this issue, researchers need to engage in ongoing reflexivity, critically examining their own positions and assumptions, and actively seeking to create a more egalitarian research environment (Chevalier & Buckles, 2019). This can be facilitated through transparent communication, capacity-building activities, and the use of participatory techniques that enable participants to voice their perspectives (Ozer et al., 2010).

Another limitation of PAR is the time-consuming nature of the process, as it involves ongoing dialogue, reflection, and collaboration among stakeholders (Chevalier & Buckles, 2019). This may lead to delays in data collection and analysis, and require additional resources for facilitation and coordination. However, proponents of PAR argue that the investment of time and resources is justified by the depth, relevance, and transformative potential of the research outcomes (Howard & Somerville, 2014).

Achieving consensus among stakeholders can also be challenging in PAR, as the diverse perspectives and experiences of participants may lead to disagreements or conflicts (Chevalier & Buckles, 2019). To address this issue, researchers need to create a safe and inclusive space for dialogue, actively promoting mutual respect, understanding, and compromise (Ozer et al., 2010). Additionally, employing consensus-building techniques, such as participatory decision-making or conflict resolution strategies, can help to navigate disagreements and foster collective ownership of the research process and outcomes (Dworski-Riggs & Langhout, 2010).

Despite these limitations, PAR offers a valuable approach for researchers seeking to engage with complex social issues and promote transformative change (Chevalier & Buckles, 2019). By involving participants in the research process, fostering reflexivity, and prioritizing action and transformation, PAR aligns with the emancipatory goals of critical social science and contributes to the democratization of knowledge production (Howard & Somerville, 2014). In conclusion, PAR provides a robust methodology for researchers who aspire to conduct research that is not only academically rigorous but also responsive to the needs, interests, and aspirations of the communities and individuals involved (Chevalier & Buckles, 2019; James et al., 2007

5.6 Case Studies

A case study is defined as a method where researchers investigate in-depth a particular context, event, process, or group of individuals (Creswell, 2003; Johansson, 2007). This study uses this approach to deeply understand the experiences of individuals within vertical social spaces (Baxter & Jack, 2008). In each case study, a phenomenological approach is employed. This method of qualitative study emphasizes understanding the lived experiences of individuals (Smith, 2015). By focusing on user perceptions and experiences within vertical social spaces, the research will provide a comprehensive analysis of the impact and effectiveness of such design practices (Langdridge, 2007).

Alongside phenomenology, this study will also integrate Participatory Action Research (PAR) within its case studies. PAR is a research method that involves the subjects of the study in the research process, allowing for the generation of solutions that are community-driven and context-specific. By involving the users of vertical social spaces in the research process, the study aims to create an empowering and inclusive design process that fully accounts for the needs and experiences of the end-users. Through the combined use of phenomenology and PAR within these case studies, the research will provide an in-depth understanding of how individuals interact with and experience vertical social spaces. Phenomenology will highlight the individual experiences and perceptions, while PAR will ensure that these insights are used to create designs that truly meet the needs of the users.

The research will adopt an embedded case study approach, treating each vertical social space as an individual unit of analysis within the broader study. This strategy will allow the application of different methods for each case, providing a rich and nuanced understanding of the experiences within various vertical social spaces. Through the integration of phenomenology, PAR, and case study methodology, this study aims to provide an empowering and user-centric approach to the design of vertical social spaces, thus ensuring their functionality and effectiveness for the users they serve.

The selection of case studies was of paramount importance in this research. Two unique prototypes of elevated public spaces in London were chosen: Sky Garden, located on the top three floors of the Walkie Talkie building, and Crossrail Place Roof Garden, an elevated park at Canary Wharf. Emerging from an extensive literature study outlined in Chapter 3 and a thorough review of London's elevated social spaces, these two case studies were selected as they were heavily publicised as open, free-access public spaces. Their distinct features concerning location, circulation, accessibility, and design, coupled with the challenges they encountered in remaining operational during the pandemic, made them especially pertinent to this study. The rationale behind this selection was to compare and analyse the different models in designing elevated social spaces. It aimed to explore various aspects such as accessibility, circulation, design, activities, security, management, and health and safety considerations, through the lens of these contrasting spaces. The focus was on understanding how users are interacting and behaving within these spaces, identifying design concerns, and evaluating how these spaces adapted to COVID-19 regulations. It scrutinized how these adaptations impacted user behaviour to further refine the critical factors of designing elevated spaces.

This approach allowed for deriving valuable insights from the users' experiences and perceptions. The aim was not only to offer a comprehensive analysis of the design practices of elevated social spaces but also to develop a framework and guidelines informed by real-world, user-centric data. This involves an examination of the impact and effectiveness of different design practices, as well as the opportunity to contribute to a more empowering and inclusive design process that is responsive to the needs and experiences of end-users.

With the adoption of an embedded case study approach, treating each vertical social space as an individual unit of analysis within the broader study, different methods can be applied to each case. This provides a rich and nuanced understanding of the experiences within various vertical social spaces. Through the integration of phenomenology, PAR, and case study methodology, this study aims to ensure the functionality and effectiveness of vertical social spaces for the users they serve.

5.6.1 Sky Garden

Among London's diverse array of vertical social spaces, this study zeroes in on the Sky Garden at 20 Fenchurch Street. Chosen for its distinctive structure, location, size, and free-entry management policy, the Sky Garden is also notable for staying operational, whenever legally feasible, throughout the COVID pandemic.

Occupying the top three floors of the 'Walkie Talkie' skyscraper in London’s financial hub, the Sky Garden (Figures 5.2 and 5.5) covers areas on levels 35-37 and also includes a specific ground floor entrance. There's just a single entry point from the ground level, situated on Philpot Lane, on the building's south-west corner (Figures 5.3 and 5.4). Entry is granted to visitors possessing either a valid free ticket or a restaurant reservation, after they undergo security checks akin to those at airports, and ascend to Level 35 in the elevator (Sky-Garden, 2015).

Most visits to the Sky Garden are scheduled via their online portal, where tickets are released three weeks ahead on a weekly basis. However, should the venue reach its full capacity, access isn't guaranteed. Visitors who miss their scheduled entry may be denied access (Viñoly et al., 2015). Once the venue reaches its capacity, visitors exceeding a one-hour stay will be asked to leave. Re-entry for pass holders is not allowed unless given special permission, and security checks must be repeated (Sky-Garden, 2015). These rules applied to the researcher as well.

The COVID-19 pandemic greatly influenced the Sky Garden's accessibility. Visitor capacity was lowered from a maximum of 600 down to a safer 200, and elevator capacity was reduced to a maximum of six guests from the same household (Figure 5.6). Owing to the minimal access points and confined indoor setting, the Sky Garden had to shut down temporarily during the 2020 governmental lockdown mandates. The Sky Garden's closure due to the pandemic posed a serious hurdle in maintaining its ventilation and indoor environment. Ensuring a pleasant and healthful indoor environment for visitors hinges on effective ventilation and air filtration systems. As a result, when the venue reopened to the public, it was crucial to ascertain that these systems were in optimal working condition to provide a safe and healthful environment.

The Sky Garden utilises a mix of natural and mechanical ventilation to maintain a pleasant and healthful indoor setting. Natural ventilation is achieved using vents and louvers, whereas mechanical ventilation involves air handling and heat recovery units that introduce fresh air and expel stale air. The Sky Garden also incorporates an advanced air filtration system to eradicate pollutants and airborne particles, ensuring a clean indoor environment (Schoenefeldt, 2016; Sky-Garden, 2015).

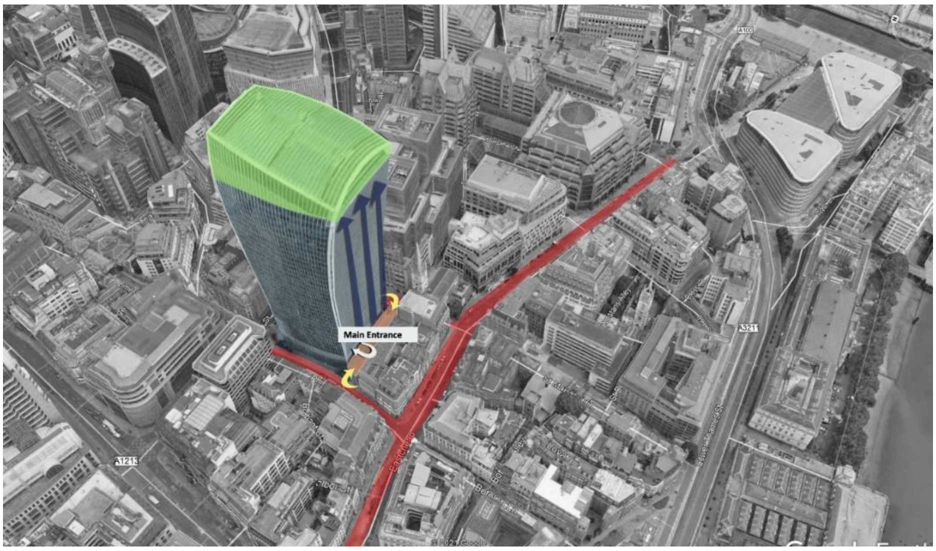


Figure 5.2. Accessibility from the street level., Source: Author.

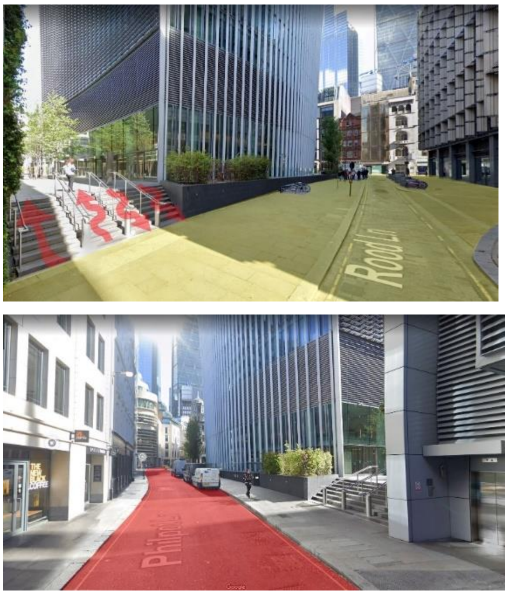


Figure 5.3. Access from Philpot Lane., Source: Author.

Figure 5.4. Entrance security checks, Sky Garden Source: Author.

Figure 5.5. 3D plan of the different activities and functions, Sky Garden, Source model: Author.

Figure.5.6. London Sky Garden, 20 Fenchurch Street, London, Source: Author.

5.6.2 Crossrail Place Roof Garden

The subsequent case study scrutinises the Crossrail Place Roof Garden located in Canary Wharf, London. The project was singled out because of its distinctive characteristics regarding location, accessibility, design, management, and activities. Spanning approximately 10,000 square metres, the Crossrail Place roof garden is an elevated, covered park constructed above the new subterranean route of the Elizabeth Line. The park's flora and their placement, spread across the 300-metre long park, are a nod to the geography and historical context of Canary Wharf (Bosetti, et al., 2019). The Canary Wharf Group's vision was to establish a community park usable throughout all seasons, and hence agreed with the local authority to construct a public roof garden atop the underground station, offsetting the dearth of green recreational areas in the London Docklands region (PLACE & WHARF, 2016) (Figures 5.7& 5.8).

Visitors can easily reach the roof garden from street level via a series of escalators or two public elevators that directly lead to the garden level (Figure 5.9). The roof garden is enveloped by a sophisticated lattice timber roof structured with ETFE vaults, promoting daylight infiltration and natural irrigation. In addition to the lush green landscape, the park houses a pub, a restaurant, and an amphitheatre. Crossrail Place, accessible to the public between 09:00 am to 09:00 pm, requires no pre-booking and admission is free. The management of Crossrail Place roof garden is executed to the same stringent standards as the rest of the Canary Wharf estate. In fact, the Canary Wharf security management plan, approved by the London Borough of Tower Hamlets, is designed to "curb crime and the perception of crime". The plan also prohibits "smoking and alcohol consumption" (except within the pub), and states that the park will be "closed in the evening". Initially, the plan was to shut the park at sunset, however, the pub and the restaurant's popularity led to an amendment in the closing time, now set at midnight. The park is also under "extensive CCTV surveillance", with footage monitored from Canary Wharf’s control room and "stored for a set period" (Bosetti, et al., 2019).

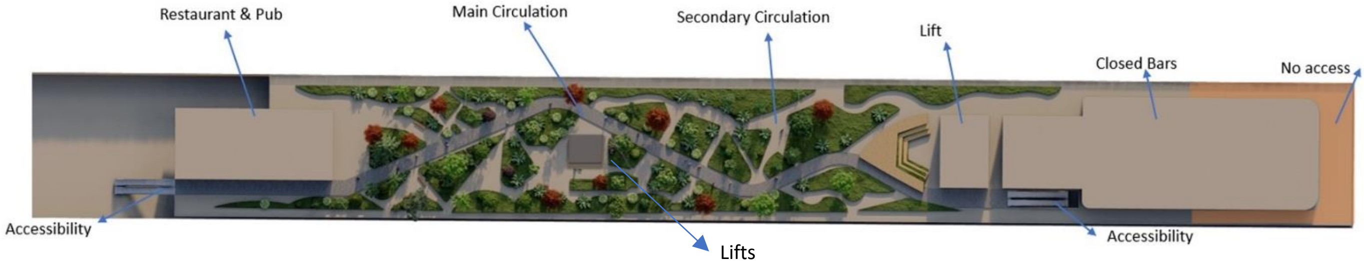


Figure 5.7 Crossrail Place Roof Garden Layout, Canary Wharf, London. Source: Author's Digital Model.

Figure 5.8 Crossrail Place roof garden, Canary Wharf, London. Source: Author.

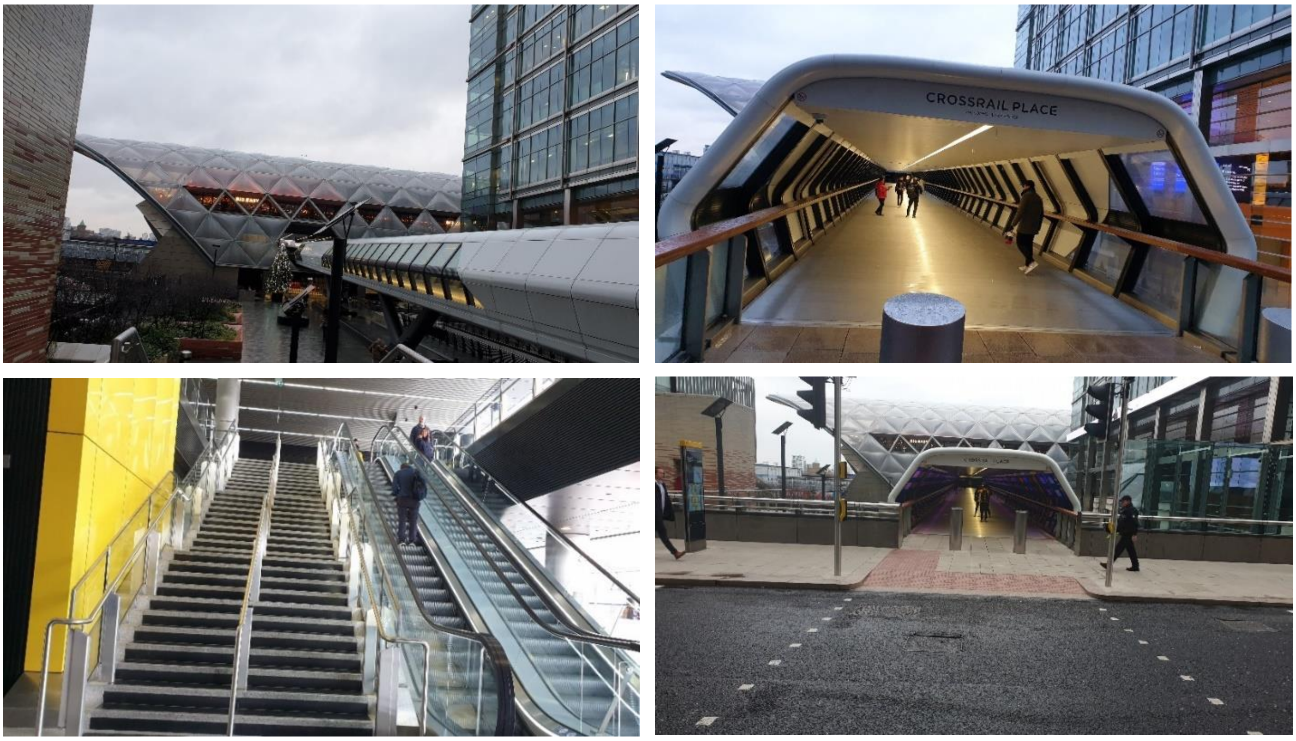
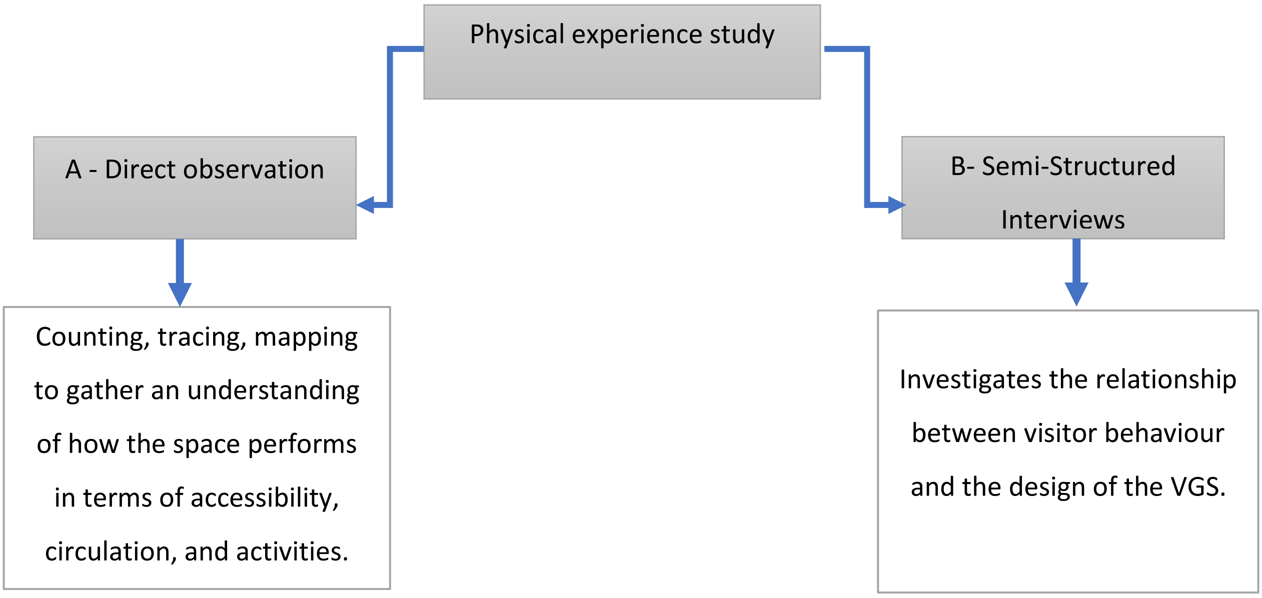


Figure.5.9 The Crossrail Place roof garden accessibility from the street level. Source: Author.

5.7 Cognitive Physical Experience

The purpose of this study was to explore how people are using vertical green social spaces before, during, and after the Covid19 pandemic. The specific objectives were to analyse the real-life cognitive experience of Crossrail Place and the Sky Garden visitors and to examine critical issues such as accessibility, circulation, activities, limitations of visitors, and social distancing. The method used in this study is a mixed approach as one tool on its own may not have provided all of the answers.



5.7.1 Direct Observation

The first method used in this study was direct observations at different times over three years (2019-2022). The research team visited the Sky Garden and the Crossrail Place before, during, and post the Covid-19 pandemic for data collection, pertaining to the movement and legibility of the space, and to observe people's activities within the space. The manual methods used for measuring the public life interaction in the space involved counting, mapping (collecting subject locations), tracing (drawing people's movement), and tracking (shadowing or following people) (Gehl & Svarre, 2013). Initially, the research objective was to scrutinise human behaviour and design aspects in elevated public gardens. However, the onset of the pandemic in 2020 prompted a significant shift in the research direction, accounting for restricted mobility and social interaction.

Various tools exist for documenting and analysing human behaviour in public spaces. The observation tools elaborated in this study primarily consist of manual tools, which can be substituted by automated methods. A crucial distinction, however, is that human registration provides more than mere 'hard data'; it also captures context-specific details that could profoundly influence the study's findings (Hanzl & Ledwon, 2017).

The 'before and after' fieldwork was imperative for data gathering to comprehend how the spatial experience evolved regarding accessibility, circulation, and activities. This technique necessitated observational data collection in 2019 and subsequent application during and post-pandemic. Several follow-up visits were made during the easing of regulations throughout 2022. The investigator visited both gardens to observe the design and the visitors utilising the spaces (refer to specific dates and times in Table 5.4 and Table 5.5).

The investigator of this study created an intricate digital model of the Sky Garden and Crossrail Place utilising the Building Information Modelling (BIM) software, Autodesk Revit 2022. This model was used to plot and scrutinise data procured during site visits. It served to illustrate and simulate shifts in visitor activities and movements over time. To analyse the critical 'pinch points' within the space, the study employed depthmapX software, which facilitated the assessment of visual accessibility via the generation of ‘point isovists’ and ‘isovist paths’.

Point isovists refer to polygons symbolising the visually accessible region from a certain point, while isovist paths delineate how the view changes when moving through the space. Furthermore, depthmapX enabled the simulation of various pedestrian behaviours by offering multiple choices for an agent on where to walk, such as towards larger spaces, along sightlines, or obscured areas of their view. The depthmapX development team has underscored the software's adaptability in analysing pedestrian behaviour in intricate environments (depthmapX development team, 2017). Broadly, the combined application of BIM software and depthmapX empowered the investigator to undertake an exhaustive analysis of the Sky Garden's spatial attributes and visitor behaviour.

The observational studies were conducted both during weekends and weekdays to facilitate a direct and equal comparison under three distinct conditions: 'pre-pandemic', 'during pandemic', and 'post-pandemic'. Observations were made in hourly intervals on both weekends and weekdays. During the official 'lockdown' period, the Sky Garden was entirely closed, preventing observation or data collection. The 'during pandemic' phase in this study refers to the post-lockdown period when vaccination was not widespread, but limited relaxation for exercise, social gathering, and travel was allowed. 'Post-pandemic' signifies the period following the UK government's announcement of lifting all restrictions. The investigator, while conducting the observations, encountered the same limitations as the public visitors, including predefined visiting times requiring prior booking, restrictions on the number of people allowed within a specific timeslot (to facilitate social distancing), a maximum stay duration of two hours, and prohibition of multiple visits in a single day.

Table 5.4: Sky Garden Data Collection Date and Time.

Sky Garden (direct observation field study)		
Date	Time	Regulations
Monday, 23/12/2019	15:00-18:00	Pre-Pandemic
Friday, 27/12/2019	9:00-12:00	Pre-Pandemic
Saturday, 11/07/2020	14:00-17:00	New rules with COVID 19
Monday, 19/10/2020	12:00-15:00	New rules with COVID 19
Friday, 21/05/2021	23:00-01:00	New rules with COVID 19
Monday, 24/05/2021	13:00-16:00	New rules with COVID 19
Thursday, 11/11/2021	11:00-14:00	Post- Pandemic
Thursday, 30/12/2021	18:00-21:00	Post- Pandemic
Saturday, 03/07/2022	15:00-18:00	Post- Pandemic
Monday, 05/07/2022	9:00-12:00	Post- Pandemic

Table 5.5: Crossrail Place Roof Garden Data Collection Date and Time.

Crossrail Place Roof Garden, Canary Wharf, London		
Date	***Time***	***Regulations***
Thursday, 26/12/2019	12:00-15:00	Pre-Pandemic
Saturday, 28/12/2019	10:00-14:00	Pre-Pandemic
Sunday, 12/07/2020	16:00-20:00	New rules with COVID 19
Sunday, 18/10/2020	12:00-16:00	New rules with COVID 19
Saturday, 22/05/2021	14:00-17:00	New rules with COVID 19
Sunday, 23/05/2021	11:00-14:00	New rules with COVID 19
Wednesday, 10/11/2021	14:00-17:00	Post- Pandemic
Friday, 12/11/2021	12:00-15:00	Post- Pandemic

Friday, 31/12/2021	13:00-16:00	Post- Pandemic
Saturday, 03/07/2022	11:00-14:00	Post- Pandemic

Adapting Gehl methods to observe the use of Crossrail Place roof garden before, during and after the pandemic:

1. **Counting:** This is a commonly used tool in public life studies. Counting provides quantitative data that can be used to qualify projects. What is often counted is the number of people moving, and the number of people partaking in stationary activities. The counting method is useful for making comparisons before and after between different spaces over time or after the application of some changes.
2. **Behaviour Mapping:** This is the representation of people's reactions and activities, with drawings, signs, and symbols in the form of a map that includes the types and frequency of human actions.
3. **Tracing people's movement**: Tracing indicates individual movements inside and around the site area. People's movements can be drawn as lines on a plan during a specific time period, such as 10 minutes or half an hour. The aim can be to collect information such as choice of direction, walking sequence, flow; which entrances are used most and which least.
4. **Photographs and films**: Photographing is an essential observation tool to document and illustrate a particular situation. Pictures and video can describe situations showing the interaction between urban form and life. It's a good tool for fast-freezing the situation for later documentation and analysis.
5. **Test walks**: This method is important as the observer has the chance to notice problems and potentials for space and its surrounding area.

The questions listed on the observation study timetable provide documentation and understanding of people's behaviour in the space (Table 5.6). The systematic questions divide visitors into subcategories and divide the variety of activities in order to get specific comparative data about people's behaviour and the use of the space before and during and after the period of pandemic regulation, at different times of the year.

Table 5.6: Template of the detailed descriptive table for the observation study (Source: Author)

Five Questions	Vertical Social space Name – Date – Time		Notes & Graphical annotations
How many	Pedestrian flow (people)	*Numbers*	*Photographs and notes*
	Stationary activity (People)	*Numbers*	
	Seating fixtures	*Numbers*	*Photographs and notes*
	Activities	*Numbers*	
	Women		
Who	Who is using the space?		*Photographs and notes*
	Gender		
	Age		
Where	Where do people move?		*Photographs and notes*
	Where do people stay?		
	Where are the activities?		
	Where are the entrances?		
	Where are the seating spaces?		
What	What are the activities?	Types of Activities related to Function:	*Photographs and notes*
	Necessary activities	Shopping	*Activities will be highlighted*
		Walking to bus	
		Working	
	Optional activities	Jogging	

		Sitting	
		Reading	*Activities will be highlighted*
		Playing	
		Eating	
		Taking pictures	*Activities will be highlighted*
		Relaxing	
	Social activities	Children playing	
		Greetings	
		Conversations	*Activities will be highlighted*
		Common activities	
		Passive contact (listening and watching others)	*Activities will be highlighted*
How Long	How long it takes people to cover a certain distance?		*Activities will be highlighted*
	How long do people stay in a certain space?		
	How long did the activity last?		

5.7.1.1 Observation Study Data Collection Samples

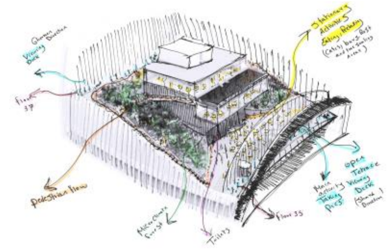
Case Study 1- Sky Garden

This includes observational data samples from the Sky Garden case study, collected over the past three years following Jan Gehl's public life study methodology (Gehl & Svarre, 2013; Gehl, 1989). Multiple visits were made to Sky Garden to observe its layout and user behaviour. A thorough analysis of the average numbers and percentages will be provided in chapter six.

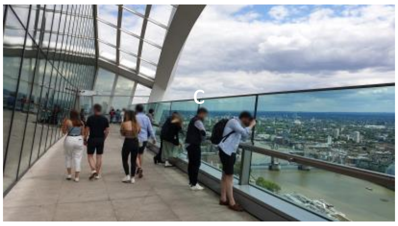
Table 5.7: Detailed descriptive analysis of the data collected (Source: Author)

Five Questions	Sky-Garden (pre-pandemic observation results) Friday, 27/12/2019		Notes & Graphical annotations
How many	Pedestrian flow (people)	220	• Around 300 visitors were visiting the place at the same time. • The maximum capacity of the Sky-Garden could reach up to 600 visitors.
	Stationary activity (People)	82	
	Seating fixtures	Around 200	
	Activities	8	
	Women	143	
Who	Who is using the space	All age groups (children, teens, adults & elderly)	• Many tourists and families visiting the place at different time.
	Gender	both Genders	
	Age	All age groups (children, teens, adults & elderly)	
Where	Where people move?	People move freely around the space up and down.	
	Where people stay?	Floor 35 In front of the café and beside the green areas	

	Where are the activities?	Outdoor viewing platform, seating area in front of the cafeteria, the bar, the restaurant & beside the green areas	
	Where are the entrances?	Floor 35	
	Where are the seating spaces?	Seating areas in front of the cafeteria & beside the green areas	
What	What are the activities?	Types of Activities related to Function:	
	Necessary activities	Shopping	
		Walking to bus	
		Working	
	Optional activities	Jogging	
		Sitting	
		Reading	
		Playing	
		Eating	
		Taking pictures	
		Relaxing	
	Social activities	Children playing	
		Greetings	
		Conversations	
		Common activities	
		Passive contact (listening and watching others)	

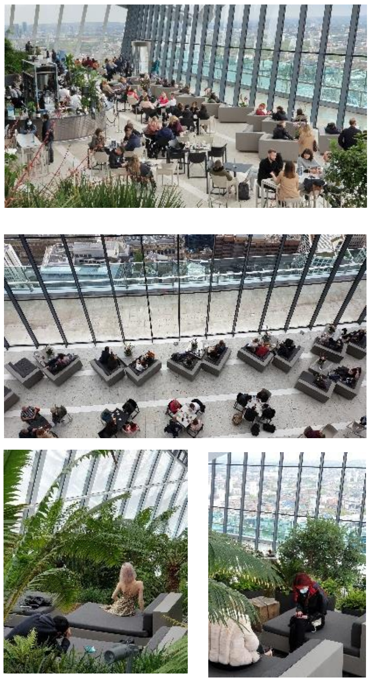
How Long	How long it takes people to cover certain distance?	20 minutes to go around the space	
	How long people stay in a certain space?	from 10 to 30 minutes depend on the activity	
	How long did the activity last?	**People on average spent one hour to two hours maximum**	

Five Questions	Sky-Garden (during-pandemic observation results) (Saturday, 11/07/2020, Monday. 19/10/2020)		Notes & Graphical annotations
How many	Pedestrian flow (people)	35-40	• The maximum number of tickets allowed per hour are for 100 visitors. • The space capacity should always have less than 200 people. • 6 guests will be permitted in the lift at any given time.
	Stationary activity (People)	70	
	Seating fixtures	Around 200 seats but only half of them are available due to social distancing rules	
	Activities	5 optional activities & 2 social activities	
	Women	60	
Who	Who is using the space	All age groups (children, teens, adults & elderly)	• The majority of people visiting the place are adults between 20 to 50 years old.
	Gender	Both genders	
	Age	All age groups (children, teens, adults & elderly)	

Where	Where people move?	Around the space in a one-way circulation	• People move in one-way circulation around the space from floor 35 to floor 36. • Floor 37 is closed till further notice. • The outdoor viewing platform is open with limited number of people.
	Where people stay?	Floor 35 in front of the café and beside the green areas	
	Where are the activities?	Outdoor viewing platform, seating area in front of the cafeteria & beside the green areas	
	Where are the entrances?	Floor 35	
	Where are the seating spaces?	Seating areas in front of the cafeteria & beside the green areas	
What	What are the activities?	Types of activities related to Function:	• The majority of people visiting the space were adults. • The main activities are taking photos, socializing, eating & drinking, relaxing and watching others.
	Necessary activities	Shopping	
		Walking to bus	
		Working	
	Optional activities	Jogging	 
		Sitting	
		Reading	
		Playing	
		Eating	
		Taking pictures	
		Relaxing	
	Social activities	Children playing	
		Greetings	

		Conversations	  
		Common activities	
		Passive contact (listening and watching others)	
How Long	How long it takes people to cover certain distance?	20 minutes to go around the spaces	• Visitors prefer to spend more time in stationary activities (eating, drinking, and relaxing).
	How long people stay in a certain space?	from 10 to 30 minutes depend on the activity	
	How long did the activity last?	People on average spent one hour to two hours maximum	

Five Questions	**Sky-Garden (during-pandemic observation results)** **Monday 24/05/2021**		**Notes & Graphical annotations**
How many	Pedestrian flow (people)	45	• A massive increase in the number of people that are in stationary activity compared with the last two visits during the pandemic. • The space capacity should always have less than 200 people. • 6 guests will be permitted in the lift at any given time.
	Stationary activity (People)	120	
	Seating fixtures	Around 200 seats but different seating orientation to allow social distance and privacy.	

		New chair beds were placed beside the green areas.	
	Activities	4 optional activities & 2 social activities	
	Women	80	
Who	Who is using the space	Tourists, friends, families and couples	• The majority of people visiting the place were adults between 20 to 50 years old. • All the bars and restaurants were opened. • All the front couches were occupied with families and couples.
	Gender	Both genders	
	Age	All age groups (teens, adults & elderly)	
Where	Where people move?	Around the space in a one-way circulation	• People move in one-way circulation around the space. • The restaurant in Floor 37 is open for guests. • The outdoor viewing platform is open with limited number of people.
	Where people stay?	Floor 35 in front of the café, beside the green areas and the restaurant in floor 37.	
	Where are the activities?	Seating areas in front of the cafeteria, stairs, beside the green areas, restaurant & the outdoor viewing platform,	• Security were watching people to make sure that visitors are following the one-way circulation system and wearing the

	Where are the entrances?	Floor 35	face mask when they are moving around. • The bar upstairs wasn't busy as people prefer to sit Infront of the outdoor terrace.
	Where are the seating spaces?	Floor 35 in front of the cafeteria, beside the green areas & the bar floor 36	
What	What are the activities?	Types of activities related to Function:	• Sitting was the dominant activity the majority of people were sitting, drinking and socialising. • New seating spaces for relaxing and sleeping.
	Necessary activities	Shopping	
		Walking to bus	
		Working	
	Optional activities	Jogging	    
		Sitting	
		Reading	
		Playing	
		Eating	
		Taking pictures	
		Relaxing	
	Social activities	Children playing	
		Greetings	
		Conversations	
		Common activities	
		Passive contact (listening and watching others)	
How Long	How long it takes people to cover certain distance?	15 minutes to go around the spaces	• Visitors prefer to spend more time in stationary

	How long people stay in a certain space?	• Sitting in a bar or a restaurant 45 – 60 mins • Moving around and talking photos 15-20 mins	activities (eating, drinking, and relaxing).
	How long did the activity last?	People on average spent one hour to two hours maximum	

Five Questions	Sky-Garden (during-pandemic observation results) DJ Night, Friday 21/05/2021		Notes & Graphical annotations
How many	Pedestrian flow (people)	40	• 6 guests will be permitted in the lift at any given time. • Restrictions are more flexible during night, most of the visitors weren't wearing facemask while moving around.
	Stationary activity (People)	165	
	Seating fixtures	Around 200 seats but only half of them are available due to social distancing rules	• Pre- booking at the Sky Garden's bars is a must. • Visitors must wear formal or smart. 
	Activities	3 optional activities & 2 social activities	
	Women	126	
Who	Who is using the space	Couples, friends & families	• Mostly millennium was using the space (couples & friends). • Less families are using the space than before and kids are not allowed to enter.
	Gender	Both genders	
	Age	All age groups (children, teens, adults & elderly)	
	Where people move?	A few numbers of people move around the space in a one-way circulation	• The outdoor deck is closed. • Victors stays in the two bars at floor 35 and 36

<table>
<tr><td rowspan="4">Where</td><td>Where people stay?</td><td>Infront of the bars in floor 35 & 36</td><td>No access to the green sating areas.</td></tr>
<tr><td>Where are the activities?</td><td>Infront of the bars and the restaurant</td><td rowspan="3">
</td></tr>
<tr><td>Where are the entrances?</td><td>Floor 35</td></tr>
<tr><td>Where are the seating spaces?</td><td>Infront of the bars in floor 35 & 36</td></tr>
<tr><td rowspan="15">What</td><td>What are the activities?</td><td>Types of activities related to Function:</td><td rowspan="4">The soft lighting and the DJ music make the design of space more suitable for couples and friends gathering.
The main activities are drinking, listening to music socializing, eating & drinking, talking selfies and watching others.</td></tr>
<tr><td rowspan="3">Necessary activities</td><td>Shopping</td></tr>
<tr><td>Walking to bus</td></tr>
<tr><td>Working</td></tr>
<tr><td rowspan="7">Optional activities</td><td>Jogging</td><td rowspan="11"></td></tr>
<tr><td>Sitting</td></tr>
<tr><td>Reading</td></tr>
<tr><td>Playing</td></tr>
<tr><td>Eating</td></tr>
<tr><td>Taking pictures</td></tr>
<tr><td>Relaxing</td></tr>
<tr><td rowspan="4">Social activities</td><td>Children playing</td></tr>
<tr><td>Greetings</td></tr>
<tr><td>Conversations</td></tr>
<tr><td>Common activities</td></tr>
</table>

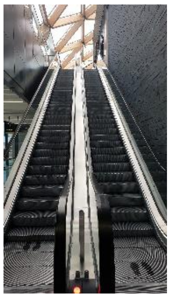
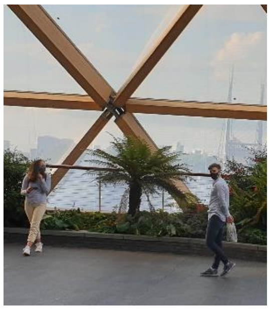
		Passive contact (listening and watching others)	   
How Long	How long it takes people to cover certain distance?	10 minutes to go around the spaces	• Visitors spend most of the time in stationary activities (drinking, listening to music & socialising).
	How long people stay in a certain space?	One hour to two hours	
	How long did the activity last?	People on average spent one hour to three hours maximum	

Case Study 2- Crossrail Place Roof Garden

This encompasses sampled observational data from the Crossrail Place Roof Garden case study, amassed over the previous three years in accordance with Jan Gehl's public life study approach (Gehl & Svarre, 2013; Gehl, 1989). Numerous site visits were conducted to examine the garden's layout and the behaviours of its users. A comprehensive analysis of the average statistics and percentages will be discussed in chapter six.

Table 5.8: Detailed descriptive analysis of the data collected (Source: Author)

Five Questions	Crossrail Place Roof Garden (during-pandemic observation results) (Saturday, 11/07/2020)		Notes & Graphical annotations
How many	Pedestrian flow (people)	23	• Around 50 to 55 visitors were visiting the place at the same time.
	Stationary activity (People)	30	
	Seating fixtures	43	
	Activities	5 optional activities & 1 social activity	
	Women	30	
Who	Who is using the space	All age groups	• The majority of visitors visiting the roof garden are adults between 21 to 50
	Gender	both Genders	
	Age	Mostly Millennials	
Where	Where people move?	People move freely around the roof garden	• People move freely around the space with less rules and regulations compared with London's Sky Garden. • No electronic security on the ground floor level.
	Where people stay?	Sunny seating spaces and the plaza.	
	Where are the activities?	Around the main and secondary circulation	
	Where are the entrances?	There are two main entrances for the Roof Garden from the ground level.	

	Where are the seating spaces?	Around the green areas and the plaza	 
What	What are the activities?	Types of Activities related to Function:	The main activities were relaxing & chilling, talking photos, socializing, eating & drinking, playing music and enjoying the green environment.
	Necessary activities	Shopping	
		Walking to bus	
		Working	
	Optional activities	Jogging	
		Sitting	
		Reading	
		Playing	
		Eating	
		Taking pictures	
		Relaxing	
	Social activities	Children playing	
		Greetings	
		Conversations	
		Common activities	
		Passive contact (listening and watching others)	
How Long	How long it takes people to cover certain distance?	15 minutes to go around the space	The restaurant and the bar were closed till further notice. Toilets were

	How long people stay in a certain space?	from 20 to 35 minutes depend on the activity	temporary closed, and the nearest toilet was inside the shopping mall.
	How long did the activity last?	**People on average spent one hour**	

Five Questions	Crossrail Place Roof Garden (during-pandemic observation results) (18/10/2020)		Notes & Graphical annotations
How many	Pedestrian flow (people)	38	• Around 75 to 80 visitors were visiting the place at the same time. • Autumn time (fall season- colourful orange trees)
	Stationary activity (People)	40	
	Seating fixtures	43	
	Activities	6 optional activities & 3 social activity	
	Women	40	
Who	Who is using the space	All age groups	
	Gender	both Genders	
	Age	Mostly Millennials	
Where	Where people move?	People move freely around the roof garden	People move freely around the space with less rules and regulations compared with London's Sky Garden. No electronic security on the ground floor level. Most of the visitors take off their face masks inside the roof garden
	Where people stay?	Sunny seating spaces and the plaza.	
	Where are the activities?	Around the main and secondary circulation	
	Where are the entrances?	There are two main entrances for the Roof Garden from the ground level.	

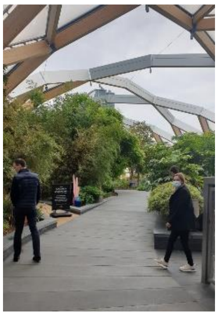
	Where are the seating spaces?	Around the green areas and the plaza	
What	What are the activities?	Types of Activities related to Function:	Jumping Game Canary Wharf Short Story Competition
	Necessary activities	Shopping	
		Walking to bus	
		Working	
	Optional activities	Jogging	
		Sitting	
		Reading	
		Playing	
		Eating	
		Taking pictures	
		Relaxing	
	Social activities	Children playing	
		Greetings	
		Conversations	
		Common activities	
		Passive contact (listening and watching others)	
How Long	How long it takes people to cover certain distance?	15 minutes to go around the space	The restaurant and the bar were closed till further notice. Toilets were temporary closed, and the

	How long people stay in a certain space?	from 20 to 35 minutes depend on the activity	nearest toilet was inside the shopping mall.
	How long did the activity last?	**People on average spent one hour**	

Five Questions	Crossrail Place Roof Garden (during-pandemic observation results) (Saturday 22/5/2021)		Notes & Graphical annotations
How many	Pedestrian flow (people)	35	• The theme of the place is different colourful Magical installation. • Around 70 visitors were visiting the place at the same time.
	Stationary activity (People)	41	
	Seating fixtures	43	
	Activities	11	
	Women	42	
Who	Who is using the space	Kids, families, couples and friends	
	Gender	both Genders	
	Age	All age group	
Where	Where people move?	People move freely around the roof garden	• Many families are coming with their kids for a picnic.
	Where people stay?	Sunny seating spaces and the plaza.	
	Where are the activities?	Around the main and secondary circulation	
	Where are the entrances?	There are two main entrances for the Roof Garden from the ground level.	

	Where are the seating spaces?	Around the green areas and the plaza	• The design is more inviting for kids surrounded by colourful art and beach features   
What	What are the activities?	Types of Activities related to Function:	New activities: Weeding photo session
	Necessary activities	Shopping	
		Walking to bus	
		Working	
	Optional activities	Jogging	
		Sitting	
		Reading	
		Playing	
		Eating	
		Taking pictures	
		Relaxing	
	Social activities	Children playing	
		Greetings	
		Conversations	

		Common activities	Hide and seek
		Passive contact (listening and watching others)	   
How Long	How long it takes people to cover certain distance?	15 minutes to go around the space	
	How long people stay in a certain space?	Around 20 minutes	
	How long did the activity last?	**Around (60 – 90) minutes**	

Five Questions	Crossrail Place Roof Garden (during-pandemic observation results) (Sunday 23/5/2021)		Notes & Graphical annotations
How many	Pedestrian flow (people)	27	• Around 45 visitors were visiting the place at the same time.
	Stationary activity (People)	23	
	Seating fixtures	43	 
	Activities	6	
	Women	24	
Who	Who is using the space	Kids, families, couples and friends	• The theme of the park attracts kids to visit the place and play around • Elderly couples were enjoying safe walking exercise
	Gender	both Genders	
	Age	All age group	
Where	Where people move?	People move freely around the roof garden	• People who are coming for a lunch break conversation mostly sitting at the middle plaza. • Couples prefer the seating spaces near the green areas.
	Where people stay?	Sunny seating spaces and the plaza.	
	Where are the activities?	Around the main and secondary circulation	 
	Where are the entrances?	There are two main entrances for the Roof Garden from the ground level.	
	Where are the seating spaces?	Around the green areas and the plaza	 

What	What are the activities?	Types of Activities related to Function:	• People feel more freely walking around the space without putting on their face masks. • Families are enjoying their time as they feel safe to let their kids play around. • Saturday afternoon the place was more vibrant and crowded. Some of the installation ground art were cut in the next day. • Sunday the place was more quitter compared with Saturday. • Modelling competition
	Necessary activities	Shopping	
		Walking to bus	
		Working	
	Optional activities	Jogging	
		Sitting	
		Reading	
		Playing	 
		Eating	
		Taking pictures	
		Relaxing	
	Social activities	Children playing	
		Greetings	
		Conversations	
		Common activities	
		Passive contact (listening and watching others)	
How Long	How long it takes people to cover certain distance?	15 minutes to go around the space	• People who are working in Canary Wharf mostly coming for lunch break. • Couples could stay for an hour (talking & taking photos) a bit longer than the average time.
	How long people stay in a certain space?	Around 30 minutes	
	How long did the activity last?	**Around 45 minutes**	

5.7.2 Semi-structured Walk-along Interviews

The study aimed to investigate the relationship between visitors' behaviour and the design of vertical social spaces. To achieve this, walk along interviews were conducted to explore the cognitive and physical experiences of space users and the impact on social interactions that occur and the factors that facilitate them (Carpiano, 2009). These interviews are embedded within a phenomenological qualitative approach that focuses on exploring the lived experiences of participants to understand the meaning and essence of a particular phenomenon (Creswell, 1998; Peters & Halcomb, 2015). The phenomenological qualitative approach is particularly useful for delving into complex, multifaceted phenomena that are difficult to measure quantitatively. It enables researchers to capture the richness, depth, and complexity of human experiences, as well as to uncover new insights and understandings that may not be apparent through other research methods (Rivera et al., 2021; Loder, 2014). This method circumvents the influences of pre-established theories that may lack such direct observational study analysis.

Walk-along interviews were carried out with a diverse age range of participants, all 18 years and older. Engaging in open-ended conversations with the participants, the researcher encouraged them to share their impressions, feelings, and opinions about the space, thereby facilitating the collection of rich, context-specific data that may not have been accessible through traditional interview techniques (Veitch et al., 2020). A total of thirty-three (n=33) interviews were conducted and analyzed at each location, with each interview lasting approximately 30 minutes. Participants were recruited on-site and provided with a study overview, the expected duration of their involvement, and an ethics consent form to sign. The information gathered through these walk-along interviews allowed for deeper insight into the participants' experiences, contributing to a more informed understanding of the factors that influence social interactions and activities within elevated urban spaces.

The author conducted a theme-based analysis using various qualitative data sets. Data were analysed using content analysis, which is an effective method for the descriptive aims (Schreier, 2014), guided by a summative approach (Hsieh & Shannon, 2005). This strategy was used to examine the ideas that make up the theme and sub-theme and how they interact with each other. The final stage was to investigate the evidence of relationships between the overarching themes, identifying the quotes that were initially hard to classify and fit into the themes and sub-themes. Sub-themes fit under the major themes in the write-up (Table 5.5 & 5.6).

The interviews analysis was divided into five stages; the first stage was creating a set of themes that were derived from the published literature and based on the theoretical concepts. The second stage focused on breaking down the interviews into chunks of data as 'sentences and paragraphs'. The third stage was allocating and labelling each sentence or a paragraph with a 'closed code' from the list of themes. The fourth stage focused on combing the individual quotes for each theme, analysing the main themes, categorising the sub-themes and investigating the relationships between themes and subthemes. The fifth stage was to construct a narrative from the themes and the codes. This stage is a description of the themes and quotes from the interviews to support and discuss the relationship between different ideas. The final stage was to investigate the evidence of relationships between the overarching themes, and also to identifying the quotes that were initially hard to classify and fit them into several themes.

5.7.3 Qualitative Data Analysis

A total of 66 interviews were conducted across both gardens. Of these, 33 were carried out at the Sky Garden in November 2021, with a gender distribution of 39.3% (n=13) male and 60.6% (n=20) female. The average age of the participants was 28.2 years. Regarding residency, approximately 36.6% (n=12) of the respondents lived in London, 39.4% (n=13) in other parts of the UK, and 24.2% (n=8) were international tourists visiting London. In comparison, 33 interviews were completed at Crossrail Place in December 2021. The gender distribution there consisted of 45.4% (n=15) males and 54.5% (n=18) females. The average age of these participants was 30.3 years. Concerning their place of residence or work, approximately 60.6% (n=20) of the interviewees lived or worked in Canary Wharf, 24.2% (n=8) resided in other parts of London, and 15.1% (n=5) were short-term visitors to London, primarily tourists (Table 5.9).

Table 5.9: Demographic characteristics of participants at Sky Garden and Crossrail Place (Source: Author)

Demographic information	Sky Garden	Crossrail Place
Interviews number	33	33
Gender		
Male	39.3% (n=13)	45.4% (n=15)
Female	60.6% (n=20)	54.5% (n=18)
Average age (years)	28.2	30.3
Residency/Work		
Living/Working in London	36.6% (n=12)	60.6% (n=20)
Living Elsewhere in the UK	39.4% (n=13)	24.2% (n=8)
International Tourists	24.2% (n=8)	15.1% (n=5)

Table 5.10: Displaying the main themes and subthemes established in the analysis (Source: Author)

Sky Garden

Themes	Sub-themes
The Choice of the space & the purpose of the visit	free to visit
	Exploring the city
	Meeting a friend
	Good attraction to show a visitor
	Social media
Activities	Checking the views
	Taking pictures
	Relaxation
	Food & Beverage
Accessibility	Online Booking
	Accessibility from the ground level
	One-way circulation system
	Security
	Publicness
Design concerns	Seating spaces
	Stairs
	Plants
	Open Space (Terrace)
	Restaurant Design
Suggestions for design Features and activities	Features that improve the design quality of the space
	Features that encourage the physical activity
	Features that encourage the social interaction.

Table 5.11: Displaying the main themes and subthemes established in the analysis (Source: Author)

Crossrail Place Roof Garden

Main theme	**Subthemes**	**Sub-sub themes**
The Choice of the space & the purpose of the visit	- Working in Canary Wharf - Living nearby - Social media - Family Picnic - Modelling competition - The Shopping mall (Canada Place) - Exploring - Working on a project	- Lunch break - Socialising - Eating & drinking - Meeting a friend - Photo shooting - Pubs and restaurants - Kids playing
Average time and duration	Visiting times in relation to needs and activities	- Rarely - Monthly - Weekly
	Seasons in relation to the physical experience	- Summer Sunny days - Autumn - Spring - Rainy days
	- Average time spent during weekends VS weekdays - Average time spent in relation to different activities	- One hour - 45 minutes - 30 minutes - 90 minutes - 20 minutes
Accessibility and Circulation	- Accessibility from the ground level - Accessibility in relation to the site surroundings - Accessibility & public transit - Access and circulation - Space circulation in relation to the physical experience	

Security and territorial rights	- The level of publicness in relation to activities and physical experience. - The level of safety and privacy - Social interaction vs. Social distancing	
Activities	- Different activities in relation to the space design - The design adaptability to cope with different themes and events - Activities in relation to the physical experience	- Necessary activities - Optional activities - Social activities
Design features and concerns affecting the physical experience	- Seating spaces design and its relation to space circulation. - Pathways width and design - Maintenance - Popping up themes - E.g.: Magical installation inspired by the Jardin Majorelle in Marrakech. - The roof design (semi-opened- semi-closed space) - Nature and landscape	
Suggested activities and design features to improve the physical experience	- Flexibility	- Different themes and events (keep changing during the year)
	- Activities	- Yoga classes - Performance events - Relaxing space
	- Design features - Features that encourage social activity - Features that encourage physical activity	- Water fountain - Kids playing area - Café - Ping-Pong tables - Covered roof space to protect from rain during winter - Comfortable and relaxing seating spaces

5.8 Virtual Study

The study employed a qualitative approach consisting of two components: (i) a VR laboratory experience; and (ii) semi-structured interviews. The Virtual Reality (VR) experiment examined two distinct methodologies and tools for the creation of interactive design models. The first model was grounded in Building Information Modelling (BIM), utilising 'Autodesk Revit' software, while the second model was based on a game engine, specifically 'Unreal Engine'. Upon completion of the VR experiment, qualitative semi-structured interviews were conducted to further explore and analyse participants' experiences, behaviours during the experiment, and interactions with the designs. The interviews primarily centred on participants' perspectives concerning their virtual experiences and behaviours throughout the study.

5.8.1 VR Experiment

The second method encompassed a two-part VR exploratory experiment involving a distinct group of participants (n=33), who were immersed in virtual interactive environments representing the Sky Garden and Crossrail Place. This approach allowed the researchers to thoroughly investigate the influence of VR technology on participants' experiences and interactions within the study, as well as to evaluate the effectiveness of the two employed methodologies in different virtual environments.

The Virtual Reality (VR) experiment examined two disparate methods and tools for developing interactive design models. The first model was based on Building Information Modelling (BIM), utilising 'Autodesk Revit' software in conjunction with the 'Enscape' plugin. The second model was grounded in a game engine, employing 'Unreal Engine' as the primary development platform. These methodologies were specifically selected due to their unique capabilities in constructing intuitive VR systems and high-fidelity models. By providing diverse options and tools for design interactions, each method addresses distinct aspects of the VR experience, ultimately offering a comprehensive and versatile platform for immersive and interactive virtual environments.

The VR experiment was divided into two distinct parts. In the first part, participants were asked to test the Sky Garden VR model, which allowed them to explore and interact with the virtual environment developed using the BIM-based method. This phase of the experiment provided valuable insights into the strengths and limitations of the BIM approach in creating immersive and interactive virtual spaces. In the second part, participants tested the Crossrail Place model, which had been developed using the game engine-based method. This stage of the experiment enabled the researchers to evaluate the effectiveness of the game engine approach in designing and constructing compelling virtual environments that facilitate user interaction.

Following the completion of the VR experiment, qualitative semi-structured interviews were conducted to further explore and analyse participants' experiences and interactions with the designs during the experiment. These interviews aimed to elicit detailed information regarding participants' perspectives on their virtual experience and behaviour throughout the study, as well as to identify any patterns or trends that emerged during the testing process. Each interview lasted approximately 30 minutes, with the conversations being recorded and transcribed. To ensure the protection of individuals, in accordance with ethical approval, the recordings were deleted after transcription. The gathered qualitative data was then analysed to draw meaningful conclusions and inform future research in the field of VR-based design models.

5.8.2 Developing an Interactive Virtual Reality Design Model:

In the VR study, the implementation of virtual reality (VR) within the construction of interactive design models is examined, utilising both software and hardware tools. Two distinct methodologies were employed in the development of these models, with each method applied to a specific case study.

The first method, employed in the construction of the Sky Garden, necessitated designing and modelling the project using 3DS Max software. Subsequently, the model was imported into Unreal Engine, utilising the Data Smith exporter plugin to convert the scene elements into Unreal Engine assets (Figure 5.10). Following the importation of the Sky Garden model, additional visual coding was required to enhance the model's interactivity. This was achieved using 'blueprinting' techniques, which incorporated interactive features into the elements of the digital model using coding method (Figure 5.11 and 5.12). Blueprint visual scripting in Unreal Engine is a comprehensive gameplay scripting system, underpinned by the concept of using a node-based interface to create active gameplay elements within the engine.

The second method, applied to the construction of the digital model of Crossrail Place, was based on Building Information Modelling (BIM). In this approach, the model was designed using BIM software, specifically Autodesk Revit 2022. This method eliminated the need for data exchange in the VR simulation, as the Enscape plugin is readily available for Revit, integrating directly with the BIM model and providing a seamless real-time visualisation in VR. Enscape allows designers to make real-time design alterations in VR while users are testing and experiencing the model (Figure 5.13 and 5.14). This approach facilitates a more efficient design process, as it enables immediate feedback and modifications to be made during the VR model exploration.

Figure.5.10 London Sky Garden model, Unreal Engine. Source: author’s model.

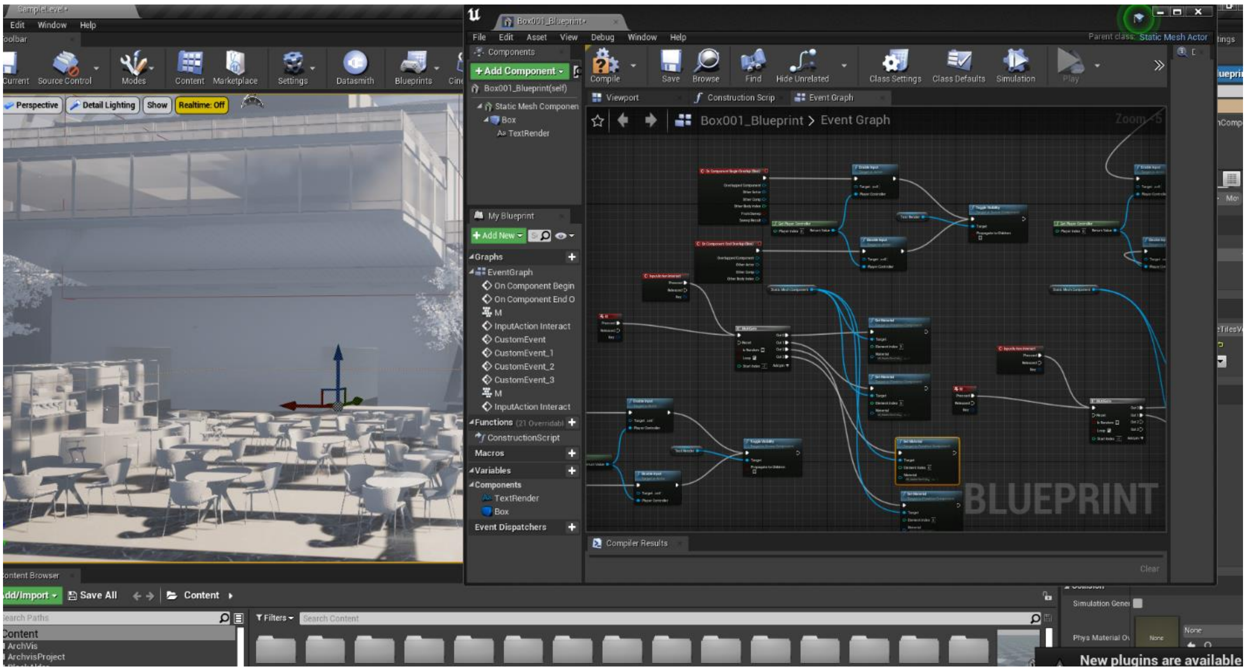


Figure.5.11, Blueprint's visual scripting method with nodes and links, Unreal Engine, source: author's model.

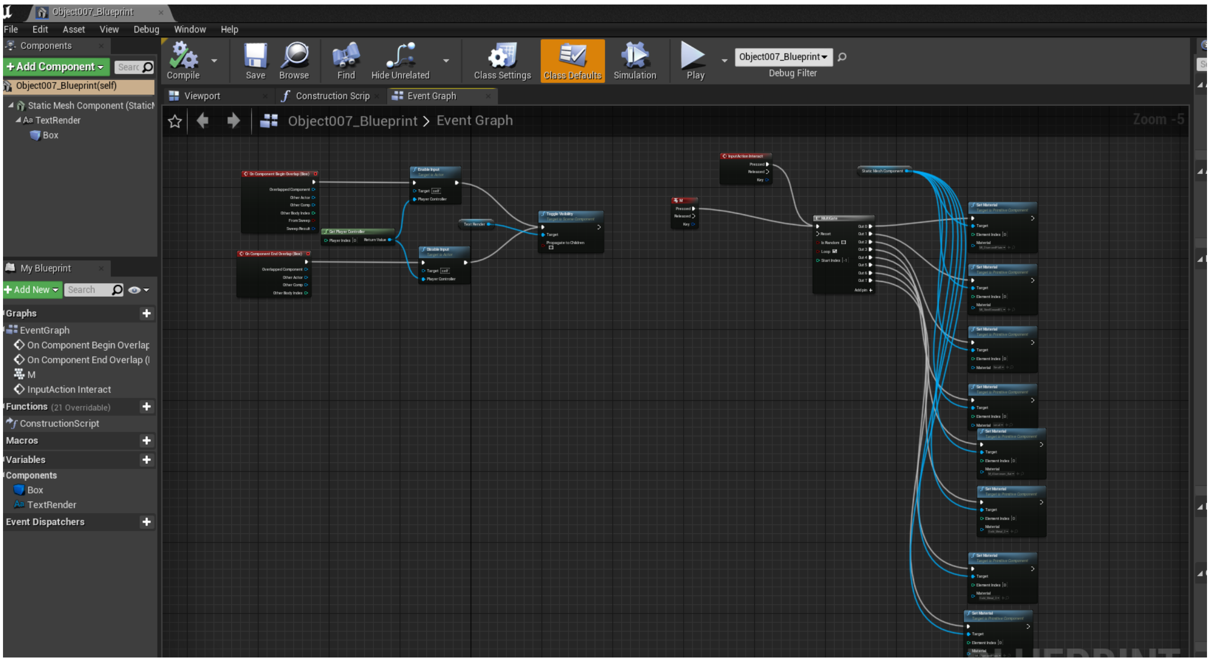


Figure.5.12, Blueprint's visual scripting method with nodes and links, Unreal Engine, source: author's model.

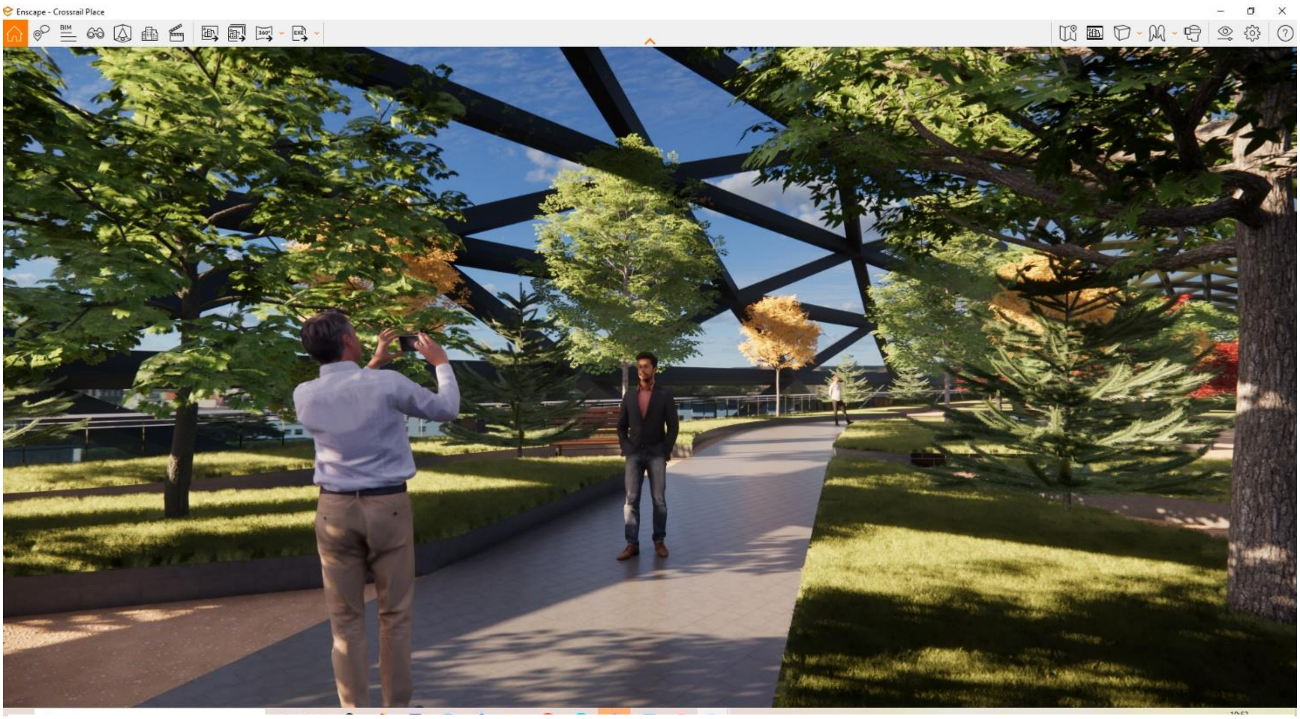


Figure.5.13 Crossrail Place roof garden model, Enscape plug-in, source: author’s model.

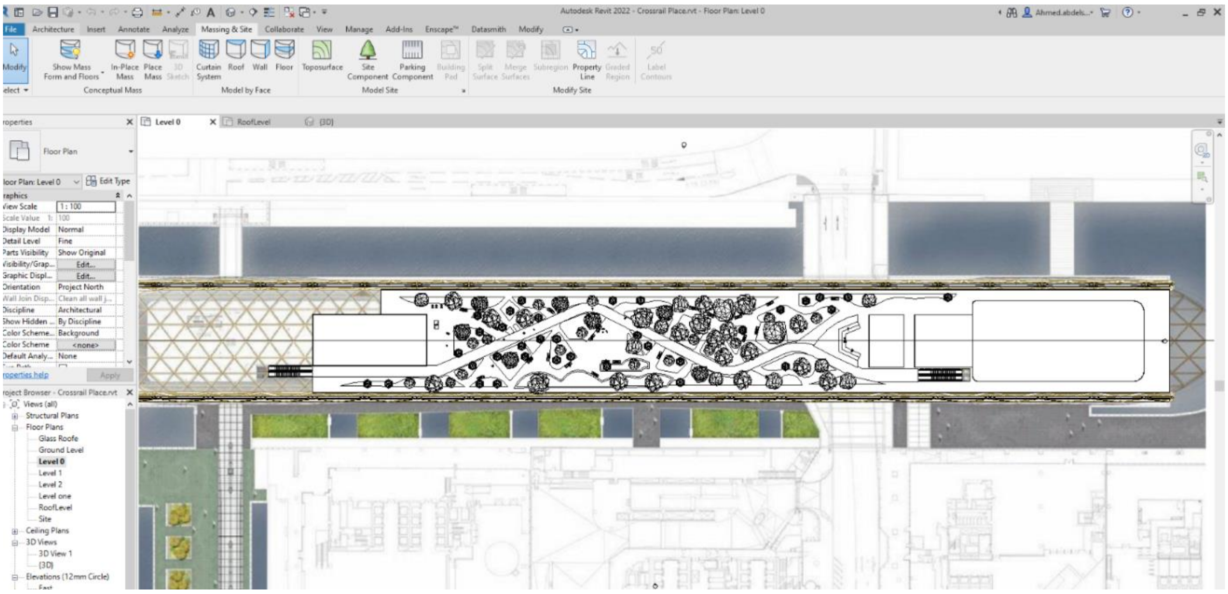


Figure.5.14 Crossrail Place roof garden project, Autodesk Revit, source: author’s model.

5.8.3 Environment & Safety Precautions

For the hardware utilised in this study, the Oculus Quest 2 was employed, which is a standalone virtual reality headset developed by Facebook Technologies, a subsidiary of Meta. To ensure safety, the Quest 2 features four integrated cameras to monitor the real environment within the laboratory setting. The headset is capable of tracking a full six degrees of motion as users navigate the virtual environment. Additionally, a GoPro 360-degree camera was used to record participants' movements within the laboratory space.

The researchers implemented safety precautions to minimise the risk of VR-induced discomfort. Proper ventilation in the laboratory was maintained, and participants were offered the option to wear an anti-nausea travel sickness wristband during the experience. The laboratory was arranged as a secure environment, devoid of immediate obstructions surrounding the user before donning the headset. The Oculus Guardian, a built-in safety feature, was also utilised to establish room-scale mesh boundaries in VR. These boundaries appeared when participants approached the edge of the designated safe experiment area, preventing them from inadvertently colliding with real walls or furniture. The VR experience was introduced progressively, limiting user exposure to 20 minutes and permitting breaks during this time. During these breaks, participants completed a personal comfort checklist, monitoring their sensations and any symptoms they may have experienced.

5.8.4 Participants

The study engaged 33 participants from diverse age groups and backgrounds, including architects, urban designers, interior designers, computer engineers, academics, and general public users (Table 5.12). Recruitment of participants was conducted using snowball sampling through various international networks. An email invitation containing detailed information about the study was sent to potential participants (Appendix B). In order to maximise the generalisability of the results and ensure that the findings are representative, targeted sampling methods were employed: (i) participants were selected from various architectural and urban design sectors, encompassing both large and small firms; (ii) academics and experts in VR, design, and public engagement were invited to contribute their insights; and (iii) public participants were categorised by different age groups and gender.

Participants classifications

Table 5.12 Displaying the participant classification in The VR study (Source: Author)

Group A	Previously visited London Sky Garden & Crossrail Place roof garden	Hadn't been to the Sky Garden & Crossrail Place roof garden before
Group B	Experts in the field • Architects • Urban Designers • Interior designers • Academics	Public and Students
Group C	Used VR before	First time using VR

5.8.5 Procedure

The virtual reality (VR) laboratory experiment was conducted over a duration of approximately one hour, during which participants engaged with VR models of the Sky Garden and Crossrail Place. These models facilitated immersive, real-time experiences, enabling participants to interact with various aspects of the environments. Participants were encouraged to explore the spaces, navigate, alter materials, adjust object positions, introduce or remove design features, modify lighting conditions, change the time of day, and capture virtual images (Figure 5.15).

Upon signing a consent form, participants were informed that they could withdraw from the study at any point if they experienced discomfort, without being obliged to provide a reason. The experiment was organised into three stages: (1) a concise presentation and induction lasting approximately 15 minutes; (2) completion of an initial survey addressing participants' demographics and previous VR experience; and (3) a 20-minute session during which participants tested the VR models and explored the spaces (Table 5.13).

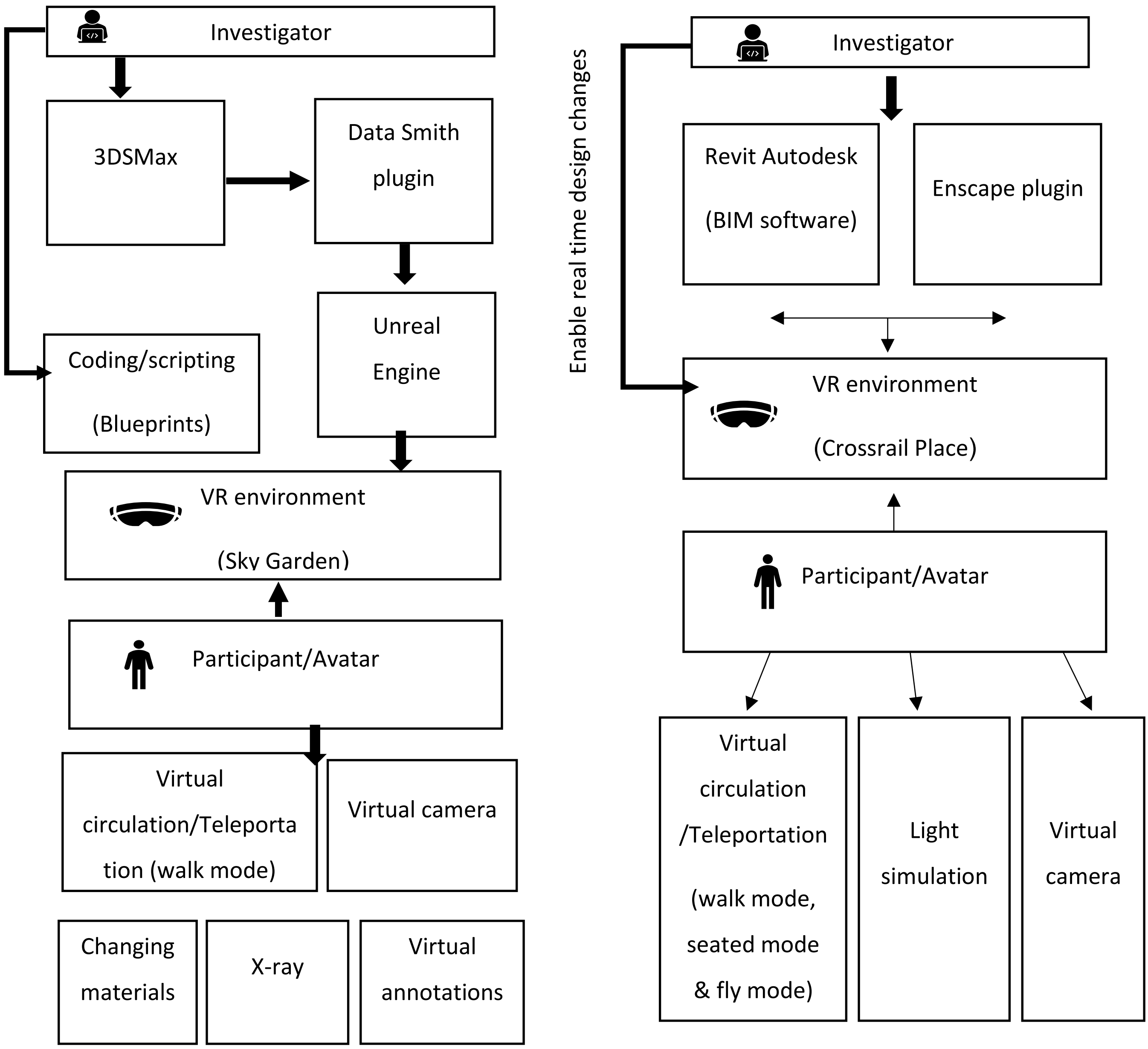
Table 5.13: VR experiment procedures (Source: Author)

Activity	Duration
Induction (health and safety and consent)	15 minutes
Survey	10 minutes
Sickness Questionnaire	5 minutes
London Sky Garden (VR experiment)	10 minutes
Break (sickness questionnaire)	10 minutes
Crossrail Place Roof Garden (VR experiment)	10 minutes
Break (sickness questionnaire)	10 minutes
Semi-Structured Interview	30 minutes

During the Sky Garden experiment, participants adhered to a one-way circulation system, in compliance with Covid-19 regulations at the actual location. They ascended the stairs within the Sky Garden in an anti-clockwise direction and interacted with the space by altering materials of floors, walls, and furniture to select their preferred design theme. They then utilised the X-Ray and virtual annotation features to modify the design and organisation of the space by repositioning or concealing objects or elements and drawing highlights or making notes. The final stage involved capturing two snapshot images of their redesigned space using the virtual camera, documenting the most appealing views and areas as if they were physically present in the Sky Garden taking holiday photographs.

For the Crossrail Place experiment, participants were encouraged to move freely within the space without following a fixed circulation path. In the subsequent stage, they were asked if they wished to add or remove design features and components in the roof garden, which they could subsequently test in real-time. The chosen design components and features were added by the researcher utilising Autodesk Revit and edited by the participants. These elements included public art, fountains, benches, flowers, animals (birds or pets), or sound effects such as waterfalls or guitar music. Participants interacted with the newly added features and elements, employing the light simulation tool and the virtual camera to render images.

Figure 5.15: A schematic representation comparing the methodologies and processes involved in the creation of interactive VR models and participant engagement with interactive design features. Source: Author.



5.8.6 Demographic Data Analysis

All 33 participants were documented and categorized into distinct groups. Group A comprised 36% (n=12) of participants who had visited London Sky Garden and Crossrail Place prior to the VR experiment, while the remaining 64% (n=21) experienced both gardens exclusively through VR during the experiment. Group B constituted 55% (n=18) public users and 45% (n=15) experts in fields such as architecture, urban design, interior design, game design, and academia. Group C consisted of 52% (n=17) first-time VR users, 42% (n=14) occasional VR users, and 6% (n=2) regular VR users (Table 5.14). The subset of participants (n=16) with prior VR experience had encountered the technology in various domains, including gaming (the most prevalent), social networking, mental health, architectural design, urban design, education, and product design, demonstrating the diverse background and experience of the study participants.

Table 5.14. Demographic survey results for VR participants

Group	Description	Percentage	Number of participants
A	Visited gardens before VR experiment	36%	12
	Exposed to the gardens only through VR	64%	21
B	Public users	55%	18
	Experts	45%	15
C	First-time VR users	52%	17
	Occasional VR users	42%	14
	Regular VR users	6%	2

The researcher conducted a theme-based analysis, utilising various qualitative data sets. Content analysis was employed as an effective method for achieving descriptive objectives (Schreier, 2014), guided by a summative approach (Hsieh & Shannon, 2005). This strategy facilitated the examination of ideas constituting the themes and sub-themes, as well as their interactions. The final stage involved investigating the evidence of relationships between the overarching themes and identifying quotes that were initially challenging to classify and fit into the themes and sub-themes. Sub-themes were incorporated under the major themes during the analysis of the research outcomes.

The interview analysis revealed three overarching themes: virtual circulation, participant interaction, and interactive design. Eight primary sub-themes (Figure 5.16) were incorporated under these major themes in the analysis, thus generating an initial structure for an interactive participatory design framework.

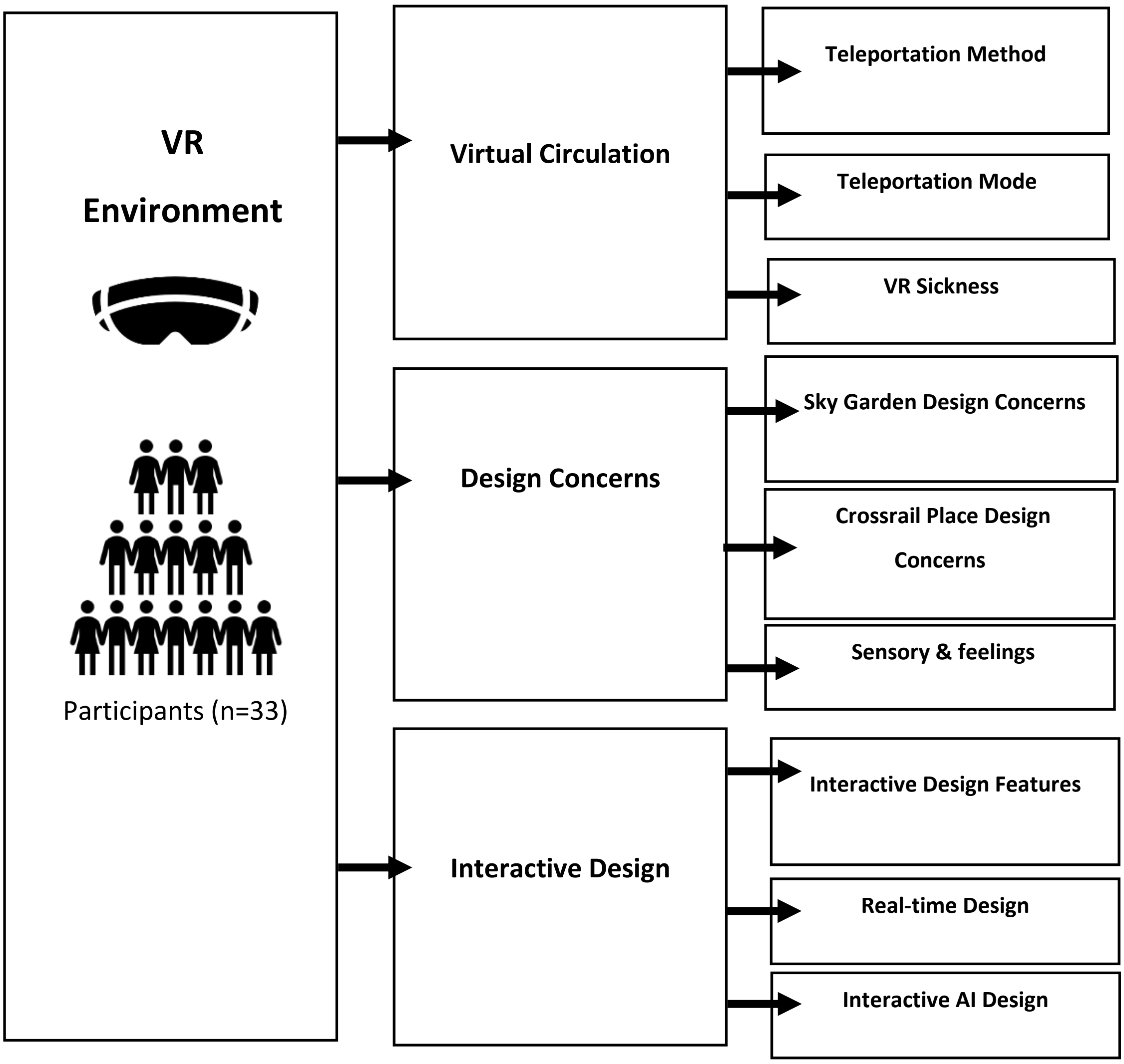


Figure 5.16 Framework displaying the main themes and subthemes for the VR experiment. Source: Author.

5.9 Ethical Considerations

This study underscored the importance of ethics, in line with Sieber's (1993: 4) emphasis that it is essentially the practical manifestation of moral values aimed at avoiding harm or wrongdoing to others, fostering goodness, demonstrating respect, and ensuring fairness. Diener and Crandall (1978) highlighted four primary ethical aspects pertinent to social research, namely the potential harm to participants, insufficient consent, violation of privacy, and deception.

In light of this, an application for ethical clearance was duly lodged and subsequently granted by the Research Ethics Committee at The University of Nottingham in advance of initiating the data gathering phase. This was achieved via adherence to a detailed protocol, encapsulating an exhaustive briefing on the architecture of the study, its cardinal objectives, and a meticulous blueprint for addressing the above-mentioned four ethical areas. In addition, all requisite consent documentation, data collection tools, and processes were submitted for perusal as part of this evaluation (Appendix A and B).

The University's protocol undertook a rigorous evaluation of specific ethical dimensions, informed by the insights of Bryman and Bell (2007), which incorporated: 1. Safeguarding against the exposure of study participants to harm; 2. Preserving and giving precedence to the dignity of the participants; 3. Securing comprehensive consent prior to launching the study; 4. Upholding participants' privacy; 5. Achieving an acceptable standard of confidentiality; 6. Providing assurance of participant anonymity; 7. Facilitating effective communication and lucid articulation of research objectives to study participants; 8. Offering transparency regarding any financial contributions; and 9. Dissemination of information about anticipated research findings and the prospective timeline for publication.

Chapter 6 (Results): Real Cognitive Experience- Direct Observation and Semi-Structured Interviews in The Sky Garden and Crossrail Place

6.1 Introduction

Chapter 6 constitutes a pivotal section in this doctoral thesis, offering an in-depth analysis of the results gathered during the investigation of human interaction with vertical social spaces across different pandemic stages - pre, peri, and post-pandemic periods. The predominant focus of this chapter is to elucidate the extent to which the architectural design of vertical urban spaces, in their multiplicity of forms and functions, can impact human behavioural patterns and subsequently influence the physical and mental health of the occupants.

To ensure a comprehensive exploration, two contemporaneous case studies were selected for detailed examination - the Sky Garden and the Crossrail Place Roof Garden. The selection of these spaces was strategically made based on the rich diversity they offer in their typologies, geographical positions, spatial dimensions, incorporation of horticultural elements, and the respective managerial policies that govern them.

In an effort to provide both qualitative and quantitative insights, a blend of methodological tools was employed, including direct observational techniques and walk-along interviews. This multifaceted research methodology was chosen not only to facilitate a detailed examination of pivotal considerations such as accessibility, circulation patterns, and prevalent activities but also to understand the restrictions imposed on visitors and the implementation of social distancing norms.

Through the lens of these methodologies, this chapter will unravel the intricate cognitive experiences provoked within these vertical social spaces. It aims to illuminate the reciprocal relationship between the design of these spaces and the well-being of the users, thereby contributing to the wider body of knowledge on urban design and its impact on societal health outcomes.

6.2 Sky Garden Case Study

In the following section, we delve into the outcomes of the observation study and interviews undertaken at the Sky Garden, both of which took place on site at varying times. The explicit dates of these studies, in addition to their principal themes, were meticulously described and emphasised within the methodology chapter under section 5.7 titled 'Cognitive Physical Study Methods'. For further insight regarding the participants involved in the study and the ethical approval and considerations see Appendices A & B.

6.2.1 Observation study results

The Sky Garden management team has indicated that the theoretical maximum capacity of the space is 600 visitors. Prior to the pandemic, an analysis of occupancy levels during hourly intervals revealed that, on weekends, the average occupancy did not exceed 310 visitors per hour (51.6% of the maximum capacity), while on weekdays, the average occupancy was 260 visitors per hour (43.3%) (see Figure 6.10). The visitors to the Sky Garden encompassed various age groups, including tourists, families, elderly individuals, and young people. An observation study conducted in the garden identified six distinct optional and social activities taking place (Figure 6.1). Among these activities, walking emerged as the primary pursuit, with approximately 190 visitors traversing the various levels of the Sky Garden, capturing city views, and appreciating the verdant surroundings. The study also found that an average of 82 visitors engaged in stationary activities, such as sitting, eating, relaxing, reading, watching others, and listening to various sounds. Notably, the outdoor observation platform was the most prominent area fostering social interaction, particularly through the act of taking pictures (Figures 6.1 and 6.2).

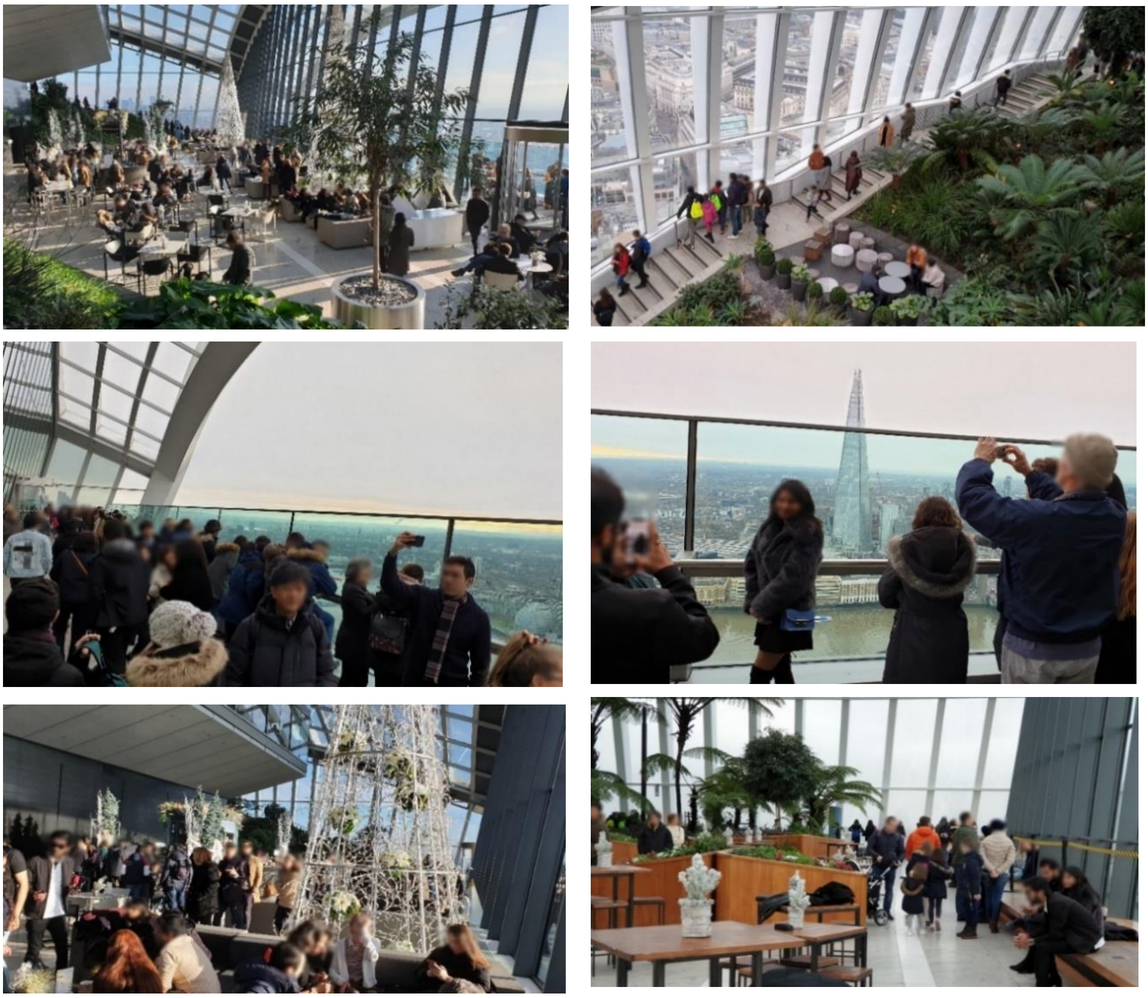


Figure. 6.1 The visitor’s activities pre-pandemic, Sky Garden, London, Source: Author, December 2019.

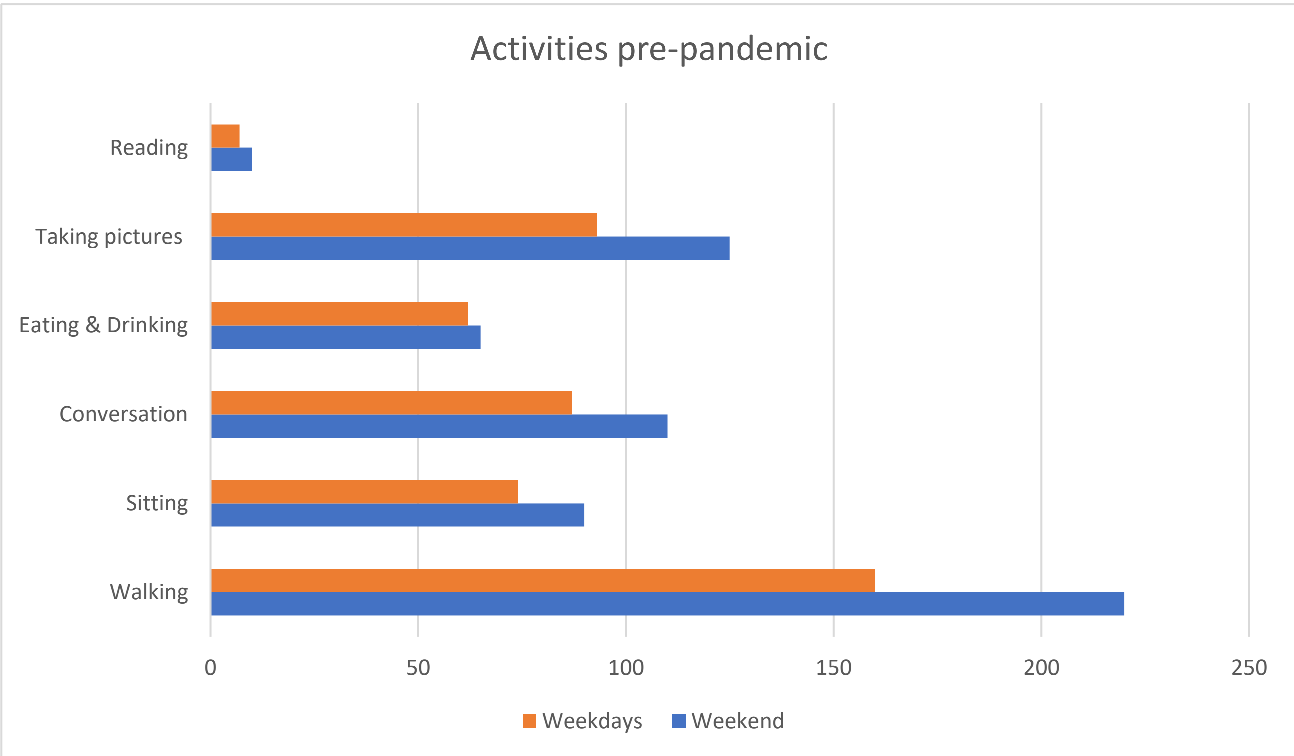


Figure. 6.2 The average number of visitor’s activities pre-pandemic, Sky Garden, London (Source: Author)

During the pandemic, the collected data revealed a substantial disparity concerning accessibility, circulation, activities, and visitor numbers at the Sky Garden. The analysis indicated a significant reduction in the concurrent presence of individuals within the space. On weekends, the average occupancy per hour was approximately 110 visitors (18.3% of the maximum capacity), while on weekdays, it stood at around 90 visitors (15%) (Figure 6.10).

By inputting the researcher's data into the depthmapx application, a connectivity map was generated, highlighting the areas with weaker connections that require further management and circulation control, namely the entrance, stairs, and outdoor terrace (Figure 6.4). Most of the findings from the space syntax analysis aligned with the observations made in the field. However, it should be noted that the visual graphic analysis of space syntax does not fully capture the practical utilization of spaces.

To manage and regulate social distancing measures, the circulation within the Sky Garden was transformed from unrestricted movement to a one-way system, specifically addressing pinch points (i.e., areas with higher risks of social distancing violations) (Figure 6.3). The management team identified areas prone to queues and implemented ground markings to clearly indicate safe social distancing practices for guests. Additionally, floor signage outside the restroom facilities played a crucial role in ensuring that guests maintained their distance while waiting to use the facilities. Floor markers were strategically placed to indicate the permitted direction of movement for all visitors throughout the venue, establishing a one-way circulation system.

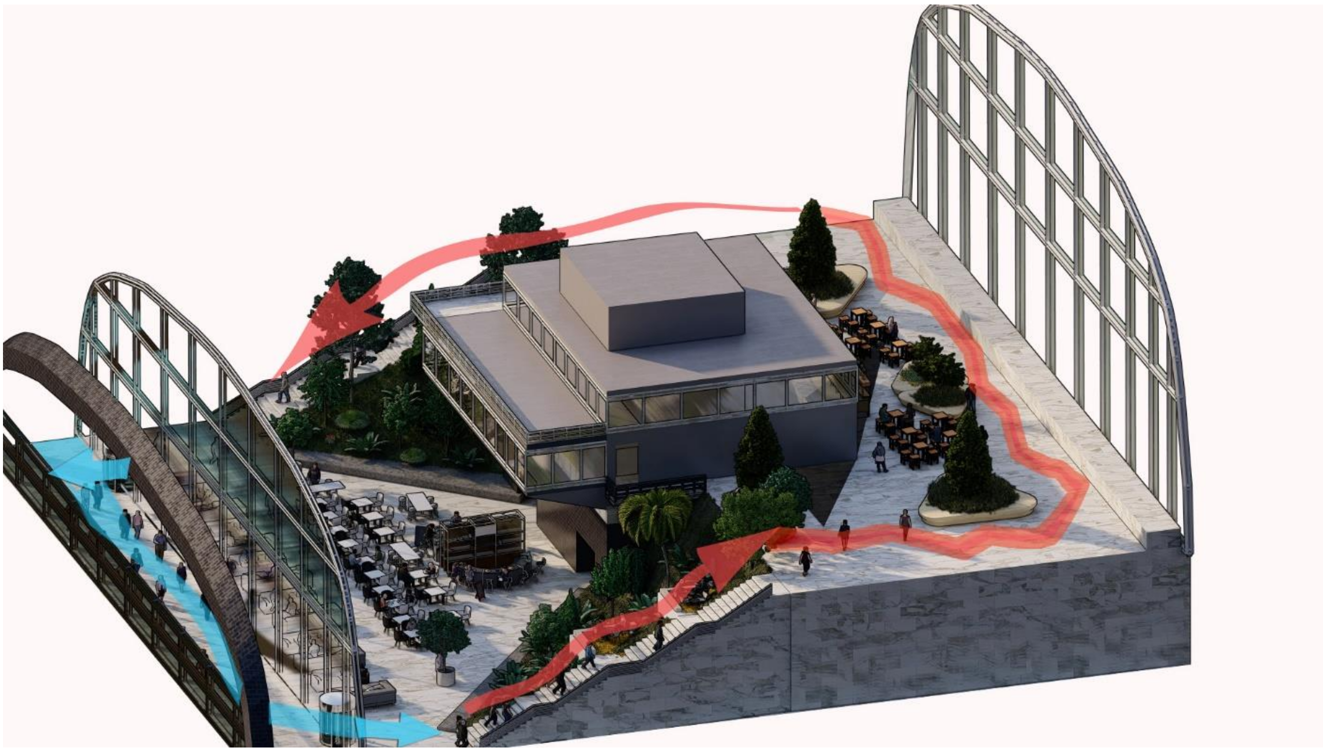


Figure. 6.3 One-way circulation system to maintain social distancing and control the pinch points, Sky Garden, Source of 3-D model and image: Author.

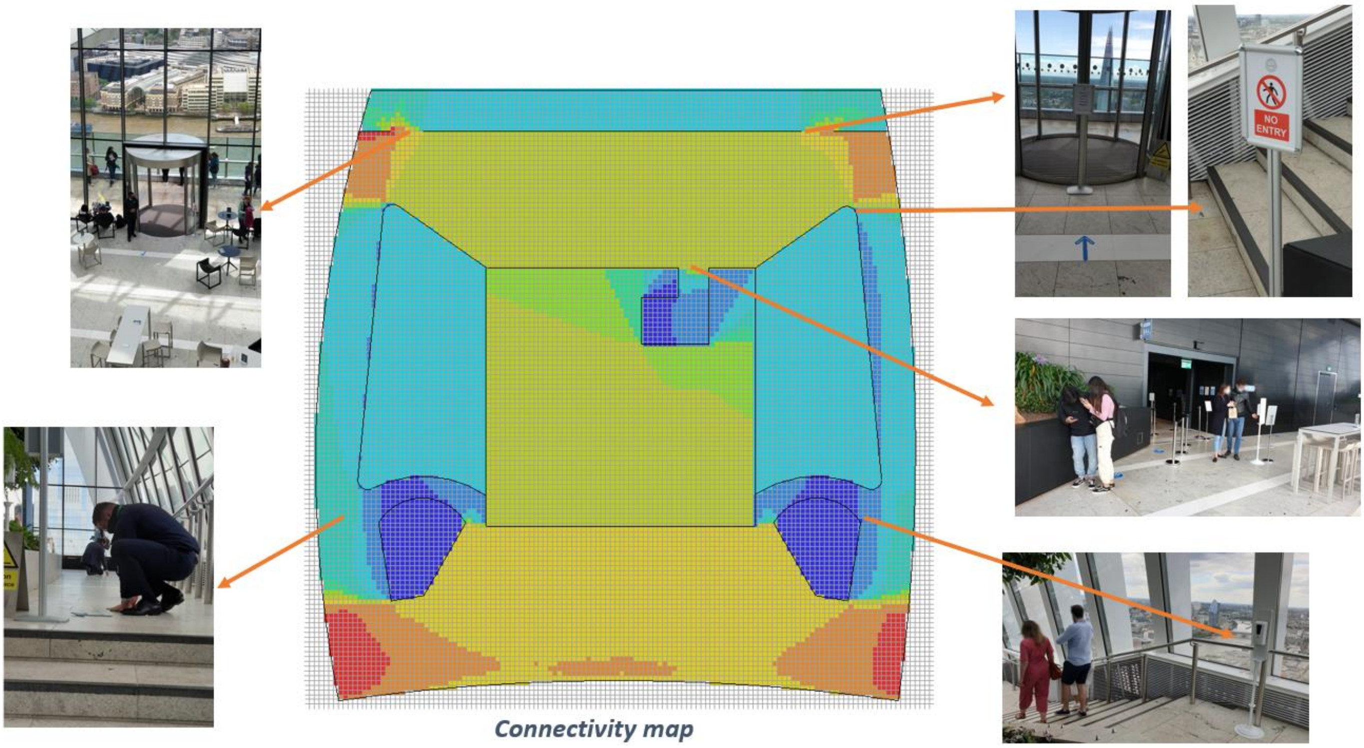


Figure.6.4 Connectivity map (using depthmapX). Each location is coloured according to how many other locations are visible from it. The range runs from blue, for low, through green, yellow to red for many visible locations, Source: Author.

The implementation of floor markers, while effective in ensuring safe distances between guests, had a significant impact on movement patterns and limited the sense of publicness within the Sky Garden. Additionally, as a safety measure, face coverings were made mandatory for visitors unless they were seated at a restaurant table or in designated bar areas.

Further analysis reveals that the one-way circulation system implemented during the pandemic had a notable influence on the activities within the Sky Garden (Figures 6.5 and 6.6). A majority of the visitors (n=70) displayed a preference for engaging in stationary activities, such as eating, drinking, and relaxing. The number of individuals involved in these stationary activities increased compared to those partaking in movement activities. The average number of people strolling in the Sky Garden simultaneously experienced a significant decline, averaging around 42 visitors. Most movement activities were concentrated on the outdoor terrace, where visitors felt safer due to the open-air environment and took the opportunity to capture photographs and relish the scenic views.

The study also highlights the emergence of new activities within the Sky Garden during the pandemic. Visitors were observed utilizing the space for working on their laptops, while the newly installed chaise lounges positioned near the plants offered opportunities for leisure and relaxation. These chaise lounges were introduced by the Sky Garden management as a response to the pandemic and have proven to be popular among visitors.

Figure. 6.5 The visitor's activities during the pandemic, Sky Garden, London, Source: Author, October 2020.

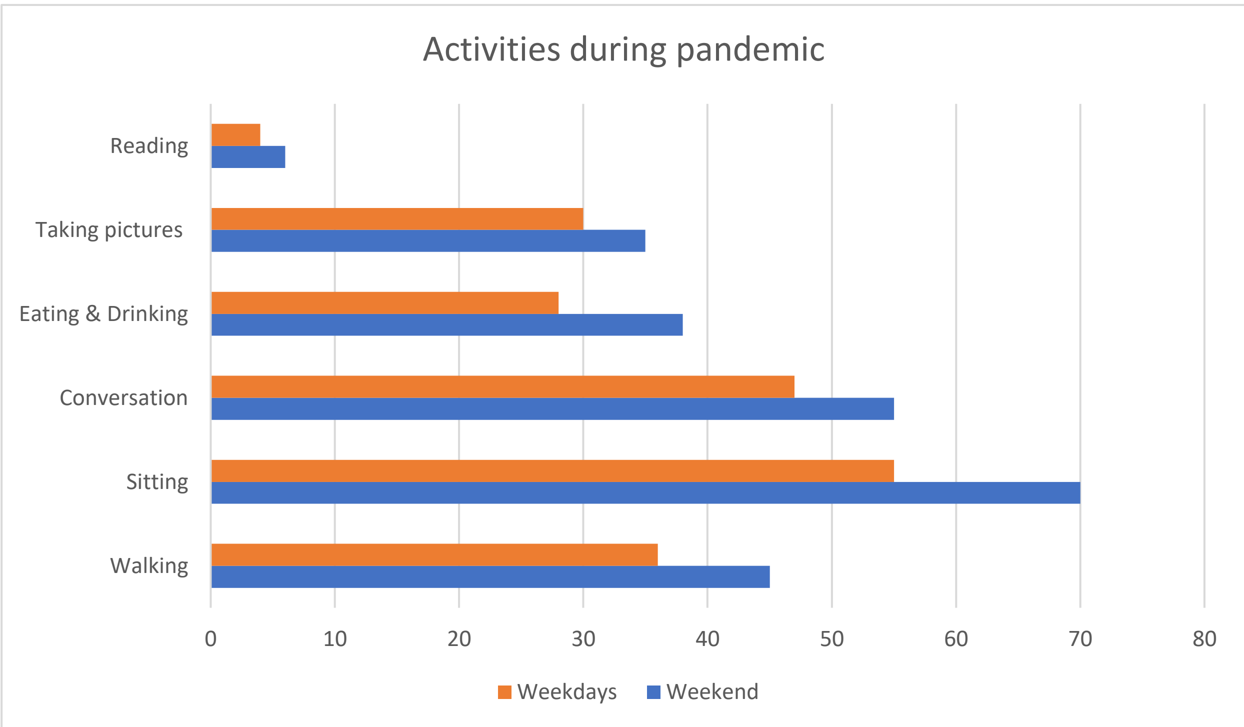


Figure. 6.6 The average number of visitor's activities during the pandemic, Sky Garden, London, Source: Author.

The analysis of post-pandemic data revealed a shift in the activities and usage of the roof garden, becoming more active compared to the pandemic period. On weekends, the average occupancy per hour reached 220 visitors (36.6% of the maximum capacity), while on weekdays, it was around 185 visitors (30.8%) (see Figure 6.10). Despite the relaxation of Covid regulations, visitors demonstrated a preference for engaging in stationary activities, such as eating, drinking, chatting, and relaxing (Figure 6.7).

The Sky Garden offers a diverse range of special events throughout the year, catering to various interests and age groups. These events encompass live music performances, cultural exhibitions, fitness classes, DJ nights, Halloween parties, and New Year's Eve parties. The introduction of these new themes and events in the Sky Garden proved inviting and interactive for many visitors, encouraging them to spend more time within the venue. However, it is worth noting that most of these events were not free for the public, and visitors were required to purchase tickets to gain entry to the Sky Garden during these organized events (Figures 6.8 and 6.9).

Prior to the pandemic, these special events were a regular occurrence in the Sky Garden. However, they were temporarily halted during the pandemic period to adhere to government restrictions. As restrictions have eased, the Sky Garden has resumed these events, increasing their frequency to attract visitors. These events offer visitors a unique and engaging experience, ranging from sunrise yoga classes to cocktail-making workshops. The frequency of these events varies depending on the season and the availability of the venue, but they typically take place multiple times per week, with an elevated number of events during peak periods such as holidays and special occasions. Designed to provide visitors with unforgettable and enjoyable experiences, these special events further enhance the Sky Garden's reputation as a sought-after destination in London.

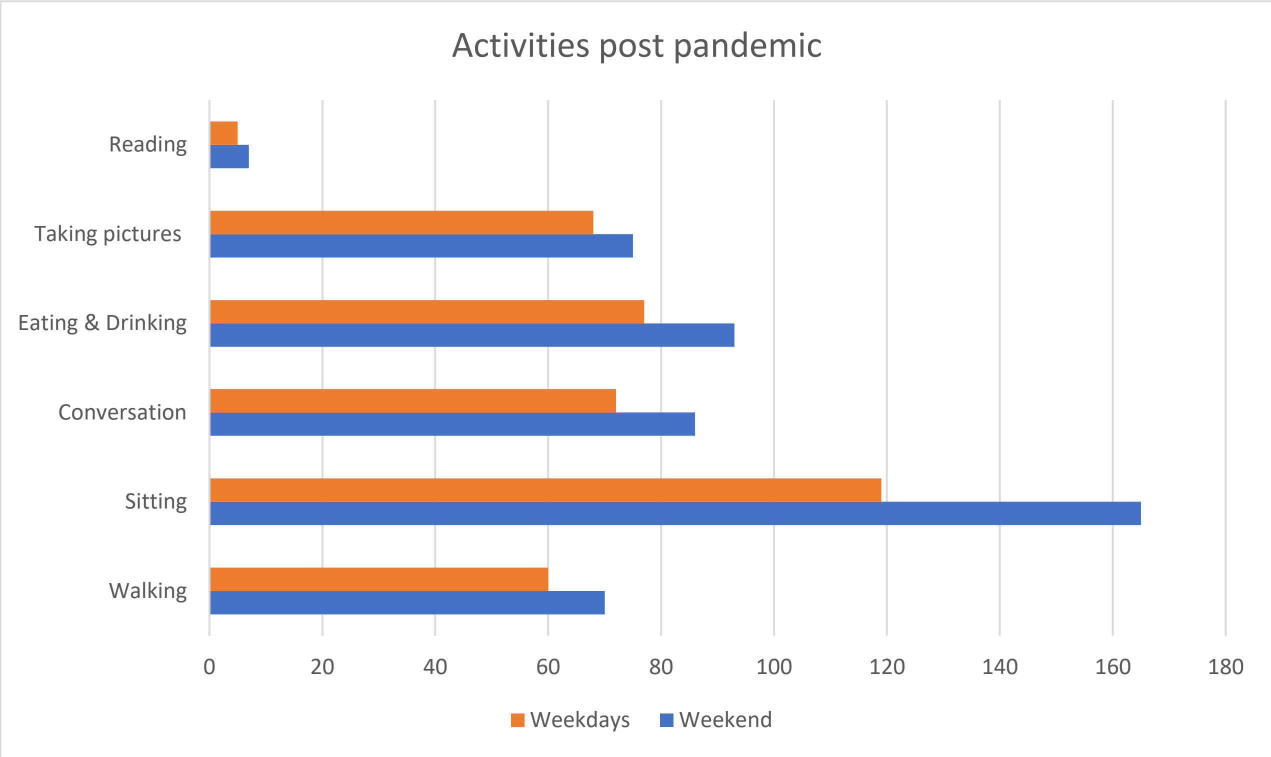


Figure. 6.7 The average number of visitor's activities during the post-pandemic, DJ night, Sky Garden, London, Source: Author.

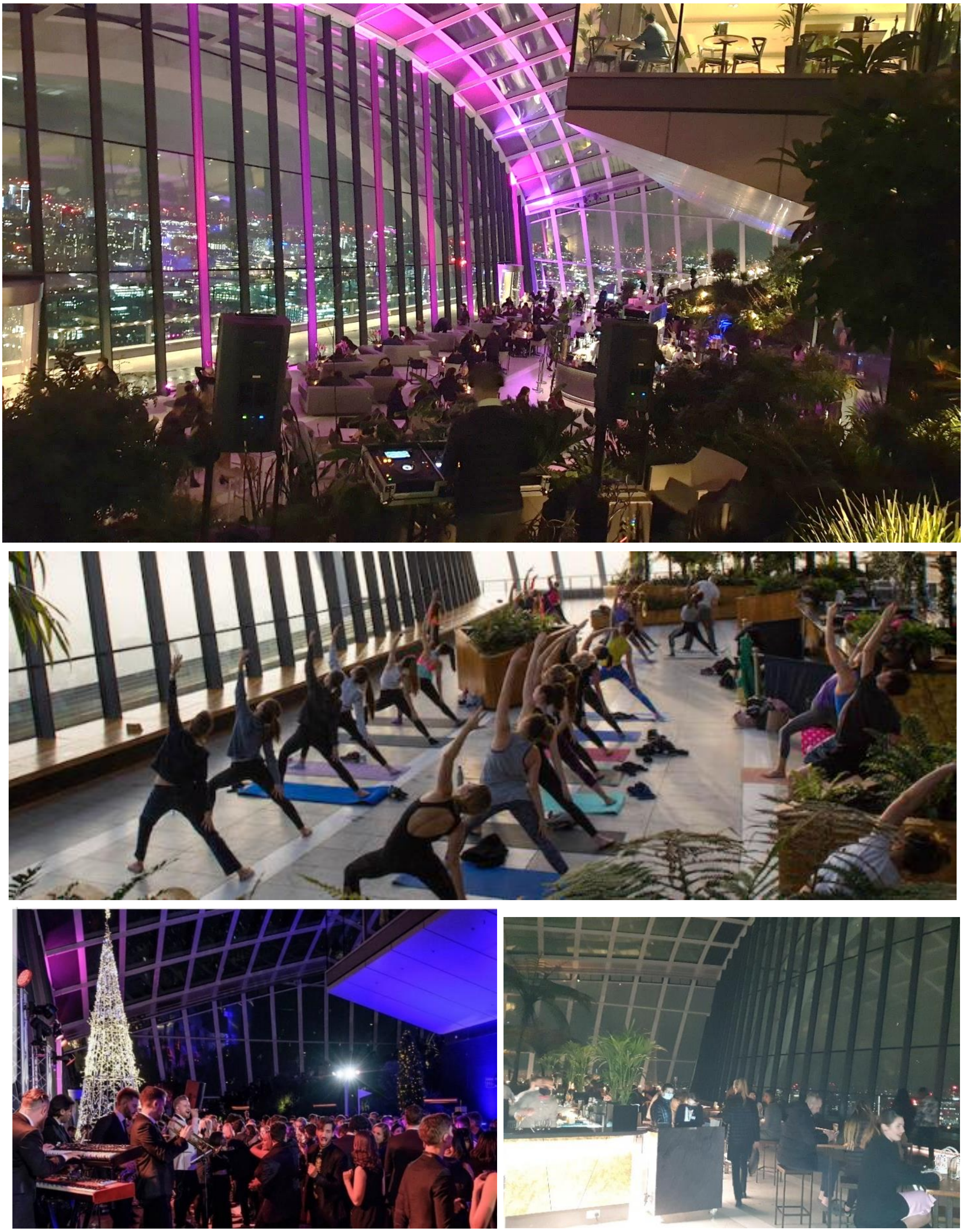


Figure. 6.8 The visitor's activities during the post-pandemic, DJ night & morning Yoga, Sky Garden, London, Source: Author, May 2021.

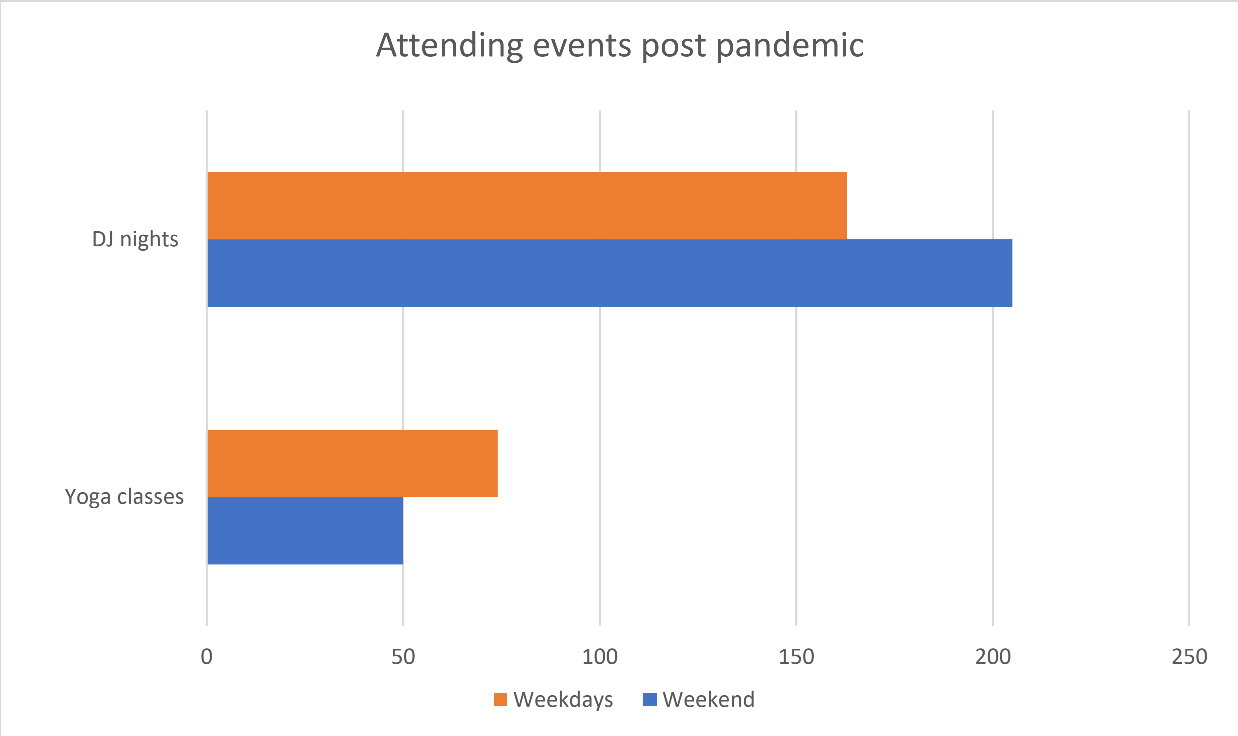


Figure. 6.9 The average number of visitors during the post-pandemic events, DJ night, Sky Garden, London, Source: Author.

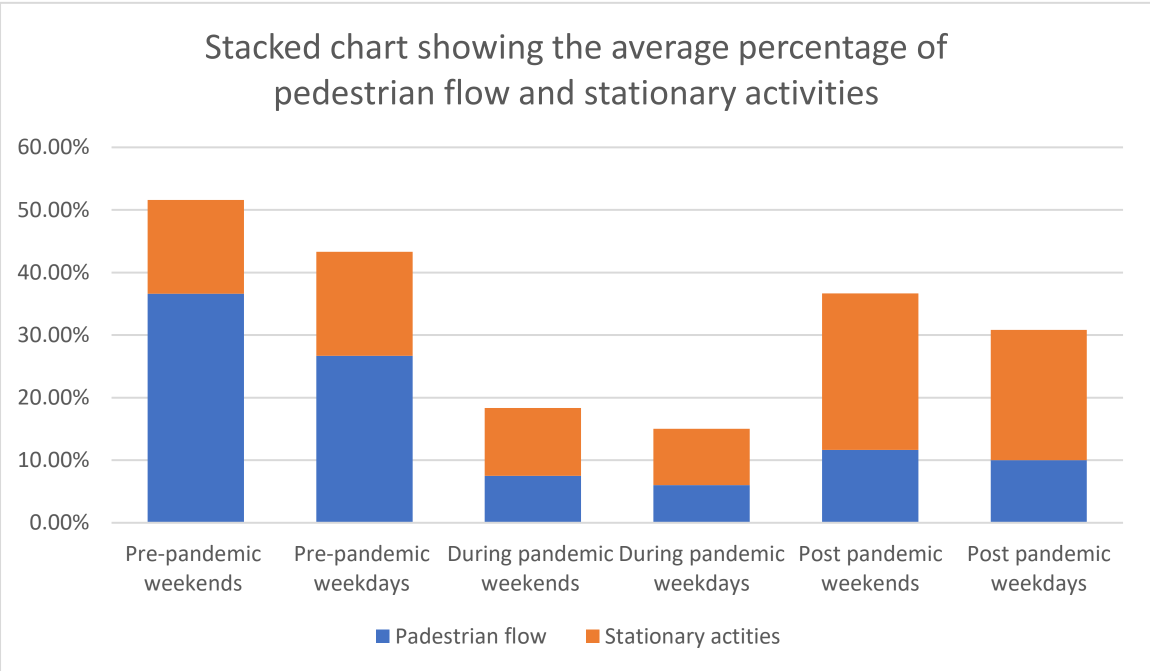


Figure.6.10 Stacked chart showing the average percentage of pedestrian flow and stationary activities at the Sky Garden before, during, and after the COVID-19 pandemic for both weekdays and weekends, as counted by the author's observation. Source: Author

6.2.2 Interviews Result

A total of 33 interviews were carried out at the Sky Garden in November 2021, with a gender distribution of 39.3% (n=13) male and 60.6% (n=20) female. The average age of the participants was 28.2 years. Regarding residency, approximately 36.6% (n=12) of the respondents lived in London, 39.4% (n=13) in other parts of the UK, and 24.2% (n=8) were international tourists visiting London. The analysis of the interviews highlights five overarching themes: the purpose of the visit; activities; accessibility; design concerns; suggestions for design features and activities.

6.2.2.1 The choice and the purpose of the visit

The choice and purpose of visiting the Sky Garden varied among participants. The most common motivations expressed by visitors were related to the panoramic view, the opportunity to explore the city of London, meeting with friends, and the fact that visiting the Sky Garden is free of charge. A considerable number of participants mentioned that the availability of free tickets incentivized their decision to visit the Sky Garden. Additionally, several participants indicated that they became aware of the Sky Garden through social media posts. The primary reasons cited by most participants for visiting and exploring the space were the breathtaking views and the advertisements highlighting the Sky Garden as London's highest public park.

“I have seen some pictures of it on social media, and it looks very beautiful. I am visiting London by myself, so I have just been doing random sightseeing to explore the city” (Female, aged 25 years, tourist from the USA).

“It is free to visit, and the views are very good” (Male, aged 27 years, living in London).

6.2.2.2 Activities

Participants in this study engaged in a variety of activities at the Sky Garden. These ranged from admiring vistas and taking photographs, to consuming cocktails, socialising, reading, and dining. Predominantly, two activities stood out among the rest: observing views of London and capturing photographs. These were cited by 16 out of the 33 participants, approximately 48.5% of the sample. Ten participants (30%) pinpointed the outdoor terrace as the optimal location for panoramic photographs of London's cityscape. However, they highlighted that accessibility to the outdoor terrace was dependent on a variety of factors, including weather conditions and visitor capacity (Figure 6.11).

One participant expressed her experience as follows: *"I had hoped for the opportunity to venture out to the terrace, but unfortunately, weather conditions precluded us from doing so" (Female, aged 24 years, UK resident, precluded by security personnel from accessing the roof terrace).*

Additionally, approximately 27.3% of participants (9 out of 33) found the Sky Garden to offer a conducive environment for relaxation. This group often chose to sit close to the greenery while reading. Despite this, a significant proportion, 16 participants (approximately 48.5% of the sample), conveyed hesitation in considering the Sky Garden as a regular destination, primarily due to the high costs associated with the venue's food and beverages. Participants criticised the Sky Garden's pricing policies and its prohibition against the consumption of outside food and drink.

In this context, a 28-year-old male living in London observed that: *"The location would be highly appealing if one were to live in the vicinity, given the lack of entry fee. It presents an opportune setting for leisurely activities such as reading a book, or to engage in work using a laptop".*

Echoing this sentiment, a 27-year-old female, also a UK resident, expressed her reservations: *"Given the high cost of even the beverages, I am hesitant to consider this venue as a regular destination."*

Figure 6.11 Visitor activities, 34th floor, London Sky Garden, London. Photo source: Author, May 2021.

6.2.2.3 Accessibility

Accessibility of the Sky Garden significantly impacts visitor behaviour, activity, and engagement within the space. During the interviews, when questioned about their perception of accessibility, particularly in the context of the Covid-19 pandemic, four salient themes surfaced: 'online booking', 'circulation', 'security', and 'publicness'. Roughly half of the participants (n=17) expressed understanding and approval for the heightened safety measures, appreciating the fact that the Sky Garden could be directly accessed from the ground level.

One participant remarked that: *"I found the accessibility quite straightforward – it took approximately ten minutes for me to reach the highest level. Given that the garden was not overly crowded during my visit, I felt comfortable and untroubled regarding social distancing norms" (Male, aged 25 years, residing in London).*

Another participant, a tourist from the Philippines, stated that: *"The measures regarding accessibility and security are reasonable, especially considering the ongoing challenges posed by the Covid-19 pandemic. I believe that the security personnel and management team are striving to maintain the safety of the premises" (Male, aged 33 years, visiting from the Philippines).*

6.2.2.3.1 Online Booking

The process of online booking emerged as a significant concern among participants. This system was frequently characterised as a hurdle to regular visitation of the Sky Garden. Numerous participants expressed their previous struggles with securing online tickets, particularly during peak times, such as weekends. Some respondents noted that the necessity to plan their visit a week in advance in order to secure a free ticket added an extra layer of inconvenience.

One tourist from Spain, a 26-year-old female, commented that: *"The level of accessibility is satisfactory, yet the booking phase can be somewhat exasperating. It would be beneficial to offer more flexible visiting hours slots on the website".*

Another participant, a 45-year-old female residing in London, recounted her booking experience: *"I recall encountering an issue with the booking. Despite several attempts, it was always fully booked, especially during the weekends".*

6.2.2.3.2 Circulation

Participants' feedback regarding the circulation system within the Sky Garden elicited a range of responses. Two primary sub-themes emerged in the discussions: the implementation of a one-way circulation system and the multi-tiered design of the Sky Garden.

Several participants acknowledged the necessity of the one-way system in light of prevailing circumstances, even while expressing minor frustrations about needing to circumnavigate the route if they wanted to revisit a particular vista. However, there were also those who appreciated this feature, noting that it promoted a more focused exploration of the space and enhanced their enjoyment of the city views.

A 27-year-old male resident of London reflected that: *"If you bypass something of interest on the left, you're compelled to traverse the entire circuit again to return to it. That could be mildly vexing, prompting me to make a few rounds".*

Contrarily, a 33-year-old female, also from London, had a more positive perspective, *"I found the one-way circulation acceptable. It serves its purpose well, enhancing the focus on the vistas and reducing the distraction caused by other visitors circulating nearby".*

The multi-level design of the Sky Garden was another key talking point among participants. Many relished the opportunity to move between different levels, suggesting that the act of ascending and descending the stairs added a dynamic, interactive aspect to the exploration of the space. However, they also recognised the potential accessibility challenges for individuals with disabilities or those using wheelchairs (Figure 6.12).

A 23-year-old female participant residing in the UK mentioned that: *"It's enjoyable to navigate between the various levels, contributing to a sense of organisation within the space".*

34-year-old male from London shared a similar sentiment, but added a note of caution, *"Personally, I have no issues with the stairs, but I can envisage the potential difficulties for those who rely on wheelchairs".*

Figure.6.12 One-way circulation system, London Sky Garden, London, source: Author, May 2021.

6.2.2.3.3 Security

Participants expressed their perceptions of security within the Sky Garden, detailing their experiences with the venue's security measures. The majority felt secure due to the notable security presence, but some participants (9 out of 33, approximately 27.3%) reported discomfort arising from a sense of being under constant surveillance by security personnel.

A 26-year-old female resident of London stated that: *"The high level of security is necessary and it enhances my sense of safety within the building".*

Conversely, a 25-year-old female, also living in the UK, found the security measures to be intrusive, stating that: *"The level of security felt somewhat excessive, given the large number of security guards present in the space".*

6.2.2.3.4 Publicness

When participants were asked to evaluate the Sky Garden's publicness in comparison to a traditional public park, responses varied. Many struggled to categorise the space strictly as public or private. A significant number of participants (19 out of 33, approximately 57.6%) described the garden as a 'private-public space'. Another group, comprising approximately 36.4% of participants (12 out of 33), viewed the Sky Garden as a private space. These participants highlighted factors such as mandatory pre-booking, the stringent security system, Covid-related rules, and usage regulations as contributing to their perception of privateness. Some also noted that the majority of seating spaces, although not all, are affiliated with bars, cafes, and the restaurant, which implies an implicit expectation of purchase.

A 26-year-old female, residing in London, observed that: *"The space feels more private, given the requirement of pre-booking and the constrained one-hour visiting slot. These factors create a certain pressure, even though I've never been asked to vacate the premises".*

A 26-year-old male, also from London, shared his perspective: *"Despite the free entry, there are numerous bars where visitors can spend money. I presume that's their primary revenue stream. This arrangement seems fairly typical for many public spaces these days, which often house food stalls".*

A 25-year-old female, visiting from the USA, pointed out that: *"Interestingly, most of the seating is tied to the bar area. Only a few places are unassociated with the bars and restaurant. It feels somewhat less public than other parks, as it seems that if you wish to sit, there's an implied requirement to purchase something".*

6.2.2.4 Design Concerns

Participants were solicited for their perceptions, both positive and negative, regarding the architectural and aesthetic design of the Sky Garden. A segment of participants, representing 26% (approximately 9 out of 33), expressed satisfaction with the garden's design, citing no major concerns. The incorporation of natural elements, such as plants and trees, was universally appreciated by the participants.

On the other hand, a significant majority, 74% (approximately 24 out of 33), voiced their concerns about the current design, suggesting various areas for potential improvement to enhance the visitor experience. Concerns often revolved around themes such as the placement and privacy of seating areas, the limited variety of tropical plants and flowers, accessibility of stairs for individuals with disabilities, the design of the outdoor terrace, and the layout of the restaurant.

A 33-year-old male tourist from the Philippines expressed that: *"Given the name 'Sky Garden', I expected a greater variety of flowers and roses. I believe that adding more green features will undeniably attract more visitors, not just for the view".*

On the matter of accessibility, a 25-year-old female tourist from the USA noted that: *"I'm uncertain about the feasibility for individuals with disabilities or mobility issues. Much of the garden experience is built around the stairs, so if one were to use the enclosed elevator, they might miss out on that aspect".*

6.2.2.5 Design features and suggested activities

The study also explored the preferences of the participants regarding the design features and activities they would like to see incorporated into the Sky Garden. Responses mainly centered around three core themes: enhancements to improve the design quality of the space; features that foster greater physical activity; and additions that encourage increased social interaction.

Suggestions to elevate the design quality of the Sky Garden ranged from practical considerations such as the inclusion of electrical sockets and drinking fountains, to aesthetic enhancements such as soft background music and the provision of more relaxing, quiet seating areas near the plants. A 45-year-old London-based participant stated that: *"The place was somewhat noisy; soft background music would offer a more calming ambience".* Similarly, a 27-year-old participant recommended, "A drinking fountain would be a refreshing addition." Another participant, a 26-year-old resident of London, suggested that: *"It would be nice to have more quiet and relaxing spaces away from the bar and café, ideally places conducive to reading a book or working on a laptop".*

Concerning features that could inspire more physical activity, the participants expressed a desire for a more varied collection of plants and flowers, each accompanied by informational tags. Many also expressed interest in guided tours, providing information about the city's views and identifiable landmarks, as a stimulating activity encouraging exploration of the space. A 26-year-old participant from the UK conveyed that: *"I think it would be interesting to have more garden-like spaces where one can walk around and learn about different plants".*

A tourist from Spain, also aged 26, shared, *"A guided tour, offering insights into the city views and landmarks, might be a worthwhile addition".*

Participants offered mixed responses when considering design features and activities to boost social interaction. Notable suggestions included live music events, placing musical instruments such as a piano, photography opportunities like photo booths, and 360-degree viewing platforms. Additionally, a few participants brought up potential activities like a table tennis area, a dedicated children's zone, and even a nightclub operating over the weekends. A 35-year-old tourist from France proposed, *"Live soft music or a piano could be a nice touch; it could create a space where people can spontaneously sit down and play music".* Echoing the interest in photography, a 25-year-old participant from the UK suggested that:, "Creating photo opportunities, such as a designated corner for a photo booth or a photo frame, could be engaging.*"* A male participant, aged 27 and based in London, affirmed that: *"Music events could be quite good; they would likely attract more visitors".*

6.3 Crossrail Place Roof Garden

This ensuing section presents an in-depth examination of the observation study and interviews conducted at the Crossrail Place Roof Garden, which took place on site during different time frames. Comprehensive details of the respective dates and key themes of these studies were previously discussed in the methodology chapter under section 5.7, 'Cognitive Physical Study Methods'. For further details about the participants of the study, along with the ethical approval and considerations, please refer to Appendices A & B.

6.3.1 Direct observation study results

6.3.1.1 Demographics & duration

The observational studies for site analysis were conducted during both weekends and weekdays, providing a basis for a balanced comparison across four different conditions: 'pre-pandemic', 'lockdown', 'during pandemic', and 'post-pandemic'. Observations were conducted in hourly intervals during both weekends and weekdays. The garden remained completely closed during official 'lockdown', thus precluding any data collection. The 'pandemic' phase in this study refers to the post-lockdown period, when vaccinations were not yet widespread, but certain allowances were made for limited activities such as exercise, social meetings, and travel. 'Post-pandemic' refers to the time subsequent to the government's relaxation of all regulations. Given that the vault's sides were open to the atmosphere, adverse weather conditions occasionally prevented interview or data collection due to the unwillingness of individuals to stop for a discussion.

The pre-pandemic analysis showed an average hourly population not exceeding 45 visitors on weekends and 34 visitors on weekdays (Figure 6.13). The garden's peak population occurred during lunch breaks from 12:00 pm to 14:30 pm. Visitors spent an average of 30 minutes during weekends and 20 minutes on weekdays in the garden (Figure 6.14). The analysis showed approximately 60% (n=24) of visitors spent about 10 minutes traversing the primary circulation path of the garden, appreciating the variety of plant species. Field observations revealed that 82% of visitors devoted around 10 to 15 minutes to seated relaxation after their walk. The analysis indicated that 43.5% (n=17) of the garden's visitors were adults, 30.5% (n=12) were young adults, 15.3% (n=6) were children, and 12.8% (n=5) were seniors (Figure 6.15).

Data collected during the pandemic showed a significant rise in the garden's visitor population. The average hourly population reached about 73 visitors on weekends and 50 visitors during weekdays (Figure 6.13). Further analysis demonstrated a notable impact of the pandemic on the increase in visitor numbers and duration of stay. The average time visitors spent in the garden increased to 50 minutes during weekends and 35 minutes during weekdays (Figure 6.14). The results showed a substantial increase in the number of young adults and children visiting the garden during the pandemic. The proportion of young adults rose from 30.5% (n=12) pre-pandemic to 40.65% (n=25) during the pandemic. Additionally, the number of children visiting the garden increased from 15.3% (n=6) to 18.5% (n=11), particularly during the weekend when families with their children (n=15) came for a picnic (Figure 6.16). The average number of adults visiting the garden during the pandemic increased from (n=17) pre-pandemic to (n=23), although their overall proportion decreased from 43.5% to 37%. The number of seniors visiting the garden remained constant (n=5) before and during the pandemic, but their proportion of the total decreased from 12.8% to 8%. This suggests that the least frequent age group visiting the garden during the pandemic was the senior group.

Conversely, post-pandemic data analysis shows a significant decline in the average number of visitors to the garden compared with the data collected during the pandemic. The average hourly population reached 54 visitors on weekends and 43 visitors on weekdays (Figure 6.13). These results indicate that the average hourly visitor population of the garden decreased by 21% post-pandemic, while it had increased by 18.5% relative to the pre-pandemic period. Furthermore, the average duration of stay in the garden increased during the post-pandemic period to reach 35 minutes during weekends and 30 minutes during weekdays (Figure 6.14). The observational study results highlighted an increase in the number of adults visiting the garden on weekdays during lunch breaks. The data show that the number of adults visiting the garden increased compared to the pre-pandemic period, reaching 20 visitors per hour during weekends and 23 visitors per hour during weekdays (Figure 6.17). The post-pandemic observational analysis also revealed a slight increase in the average number of children from (n=6 pre-pandemic) to (n=8 post-pandemic), and young adults from (n=12 pre-pandemic) to (n=16 post-pandemic).

While the results indicate an overall increase in the number of individuals utilising the garden after the pandemic, there remained a substantial decline in the average population and duration of stay compared to the pandemic period. These aspects will be further examined and analysed in the subsequent semi-structured interviews with the participants.

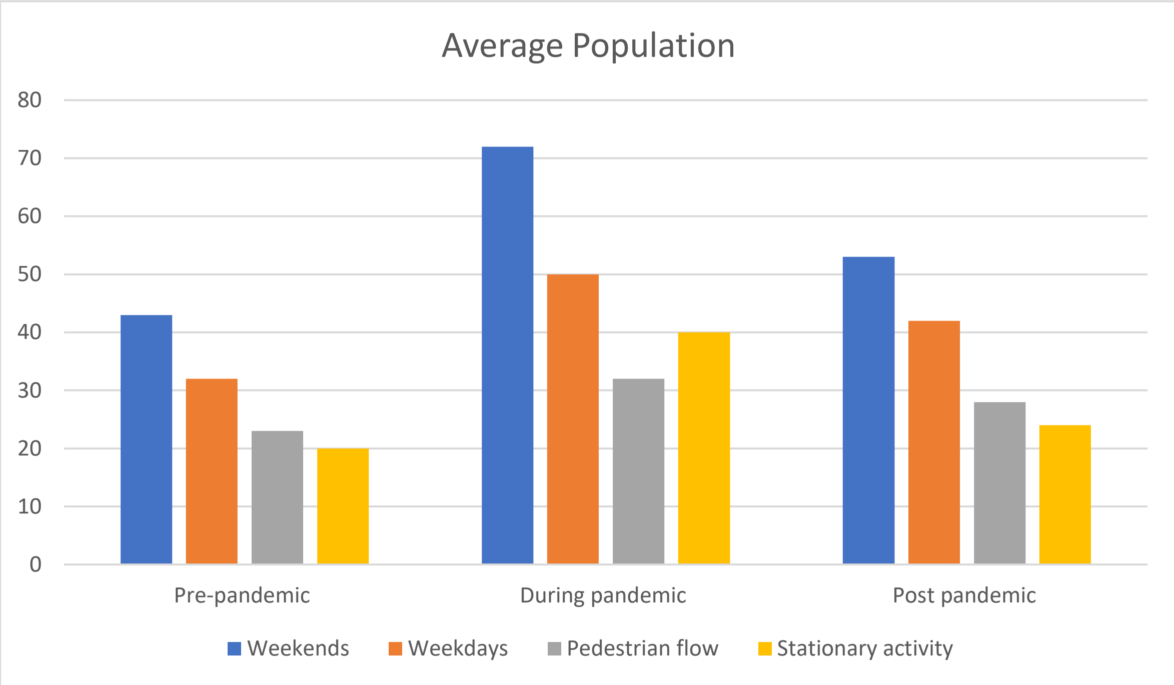


Figure.6.13 Crossrail Place roof garden visitor's average population. Source: Author.

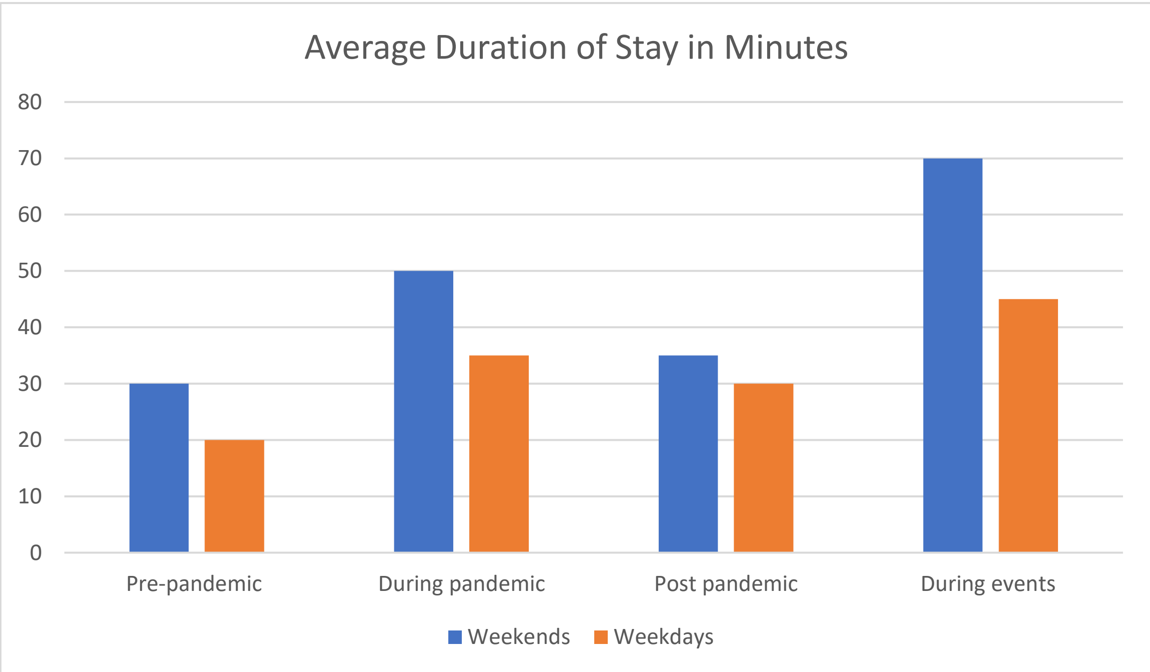


Figure.6.14 Crossrail Place roof garden visitor's average duration of stay in minutes. Source: Author.

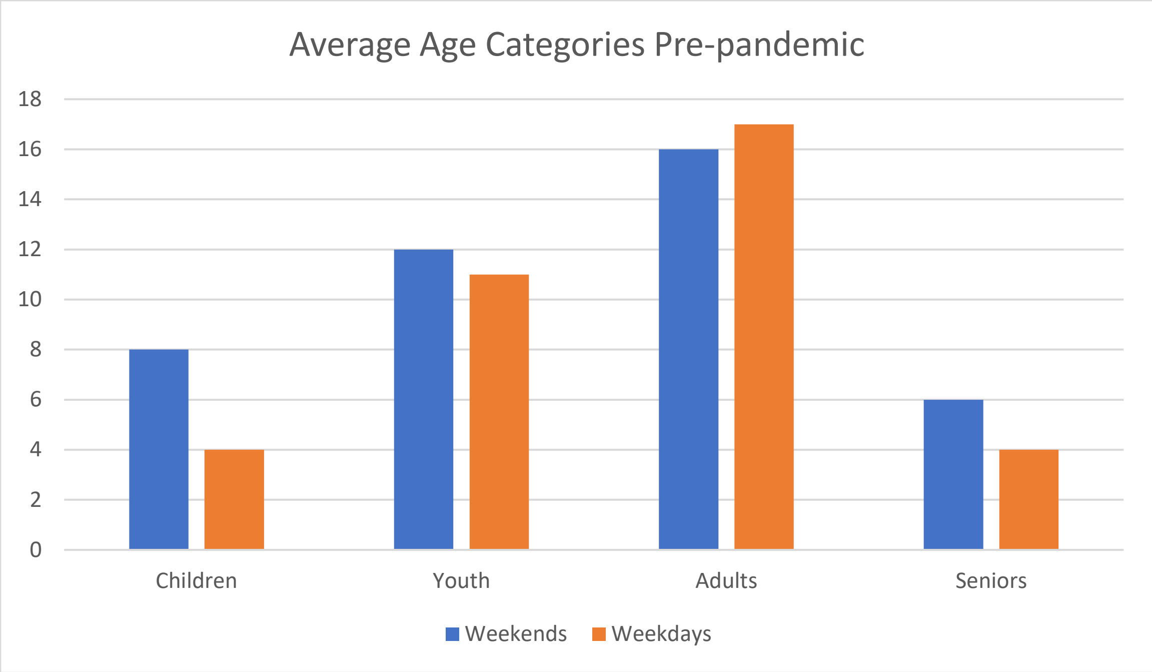


Figure.6.15 Crossrail Place roof garden visitor's average age categories pre-pandemic. source: Author.

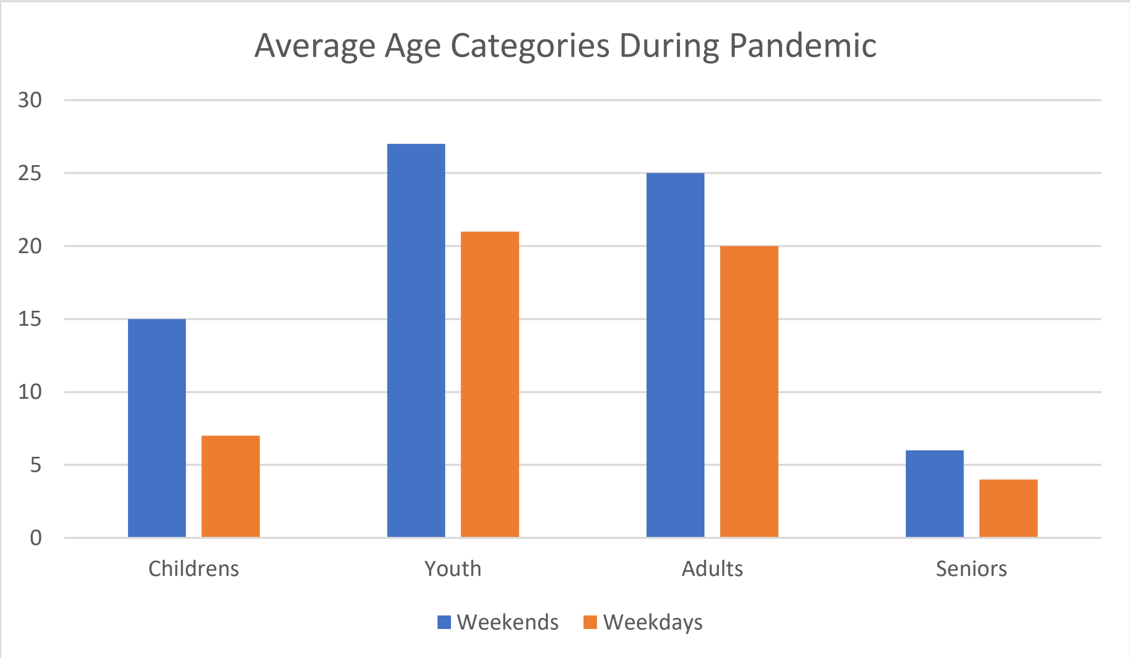


Figure.6.16 Crossrail Place roof garden visitor's average age categories during pandemic, source: author.

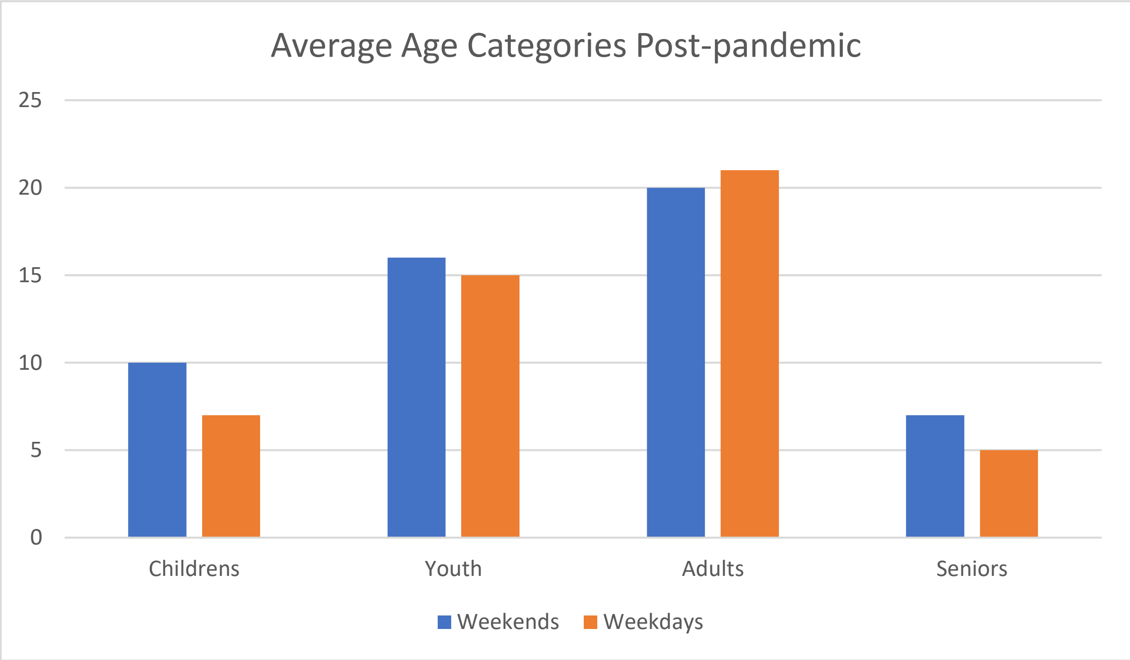


Figure.6.17 Crossrail Place roof garden visitor's average age categories post pandemic, source: author.

6.3.1.2 Activities

Observations conducted during the pre-pandemic period documented six distinct optional and social activities occurring in the garden. The primary activity observed was walking, with visitors frequently strolling around the garden, capturing photographs, and admiring the plants. Other individuals were observed seated on the wooden benches, conversing or consuming food and drinks with their companions. These individuals were predominantly employees from Canary Wharf, preferring to take their lunch breaks in the garden. The amphitheatre was sparingly used, primarily by families. A substantial number of individuals merely passed through the garden to access the bar or restaurant. Despite the bustling environment of the garden, social interaction appeared to be minimal. An exception was the presence of a piano at the entrance, around which a few people engaged in activities such as listening to others or capturing photographs (Figures 6.18 and 6.19).

Figure.6.18 Crossrail Place roof garden visitor's activities pre-pandemic. Source: Author, December 2019.

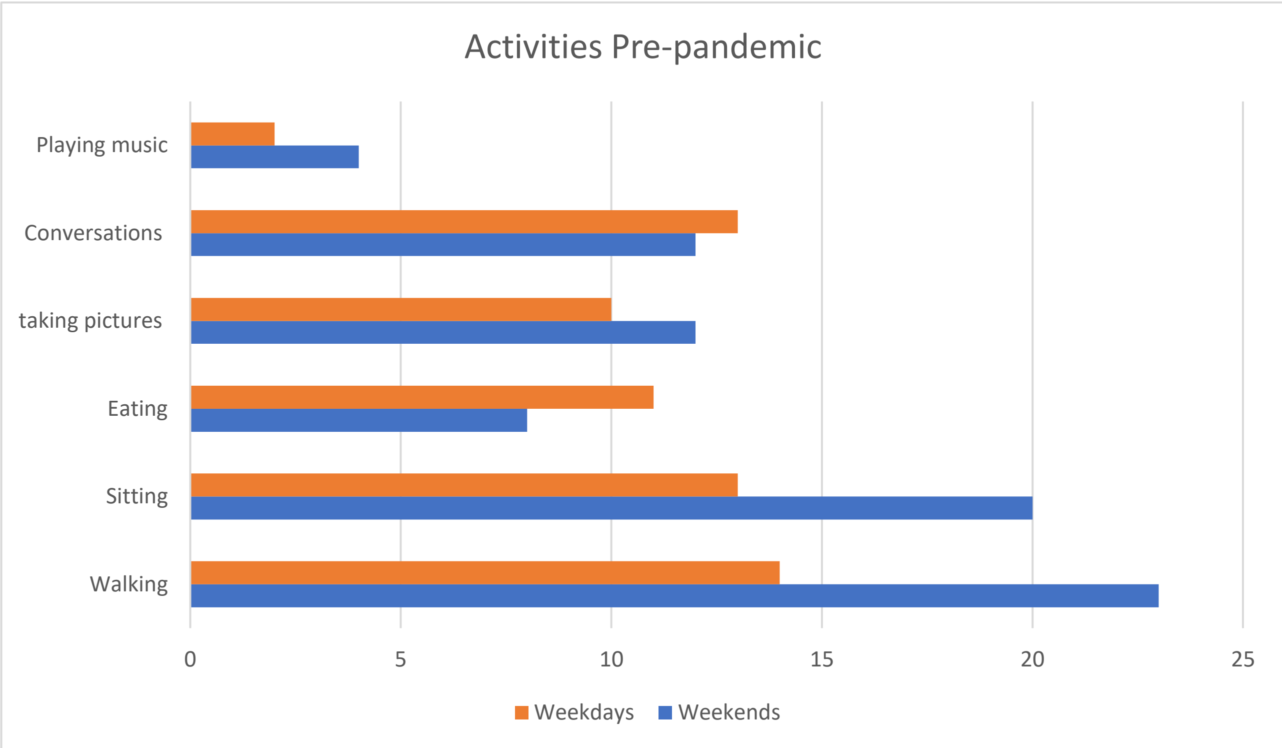


Figure.6.19 Bar graph for the average number of visitor's activities pre- pandemic. Source: Author.

During the pandemic, the data revealed the emergence of new activities within the garden, such as reading, relaxing, and playing. Some individuals opted to spend their time alone in the garden, seated on wooden benches near the plants, engaged in relaxation or reading. Newly installed touch-free sensor-enabled short story stations in the garden encouraged reading. The number of individuals seated in the garden noticeably increased from the pre-pandemic period, with a rise in the number of families and children visiting for picnics during weekends. Children primarily played and ran around in the garden, with a new jumping game positioned near the garden's entrance proving popular. Inhabitants of Canary Wharf frequented Crossrail Place to meet friends, perceiving the garden as "a safe place to meet friends and hang out in a green environment". This aspect was further explored during the semi-structured interviews (Figure 6.20 and 6.21).

Figure.6.20 Crossrail Place roof garden visitor’s activities during the pandemic. Source: Author, July 2020.

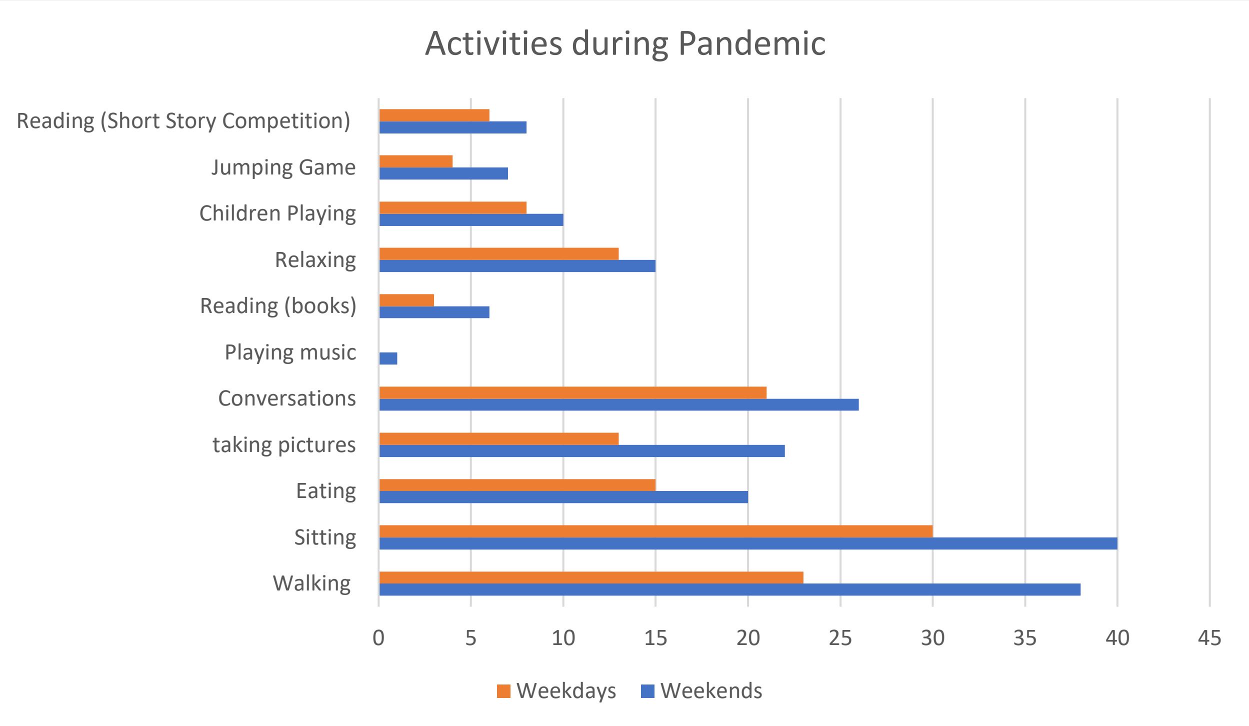


Figure.6.21 Bar graph for the average number of visitor's activities during pandemic, source: Author.

From the 29th of March to the 19th of June 2021, during late spring, a 'Magical Installation' inspired by the Jardin Majorelle in Marrakesh was set up in the garden. Observational data highlighted a significant surge in garden visitation during this installation. New activities, such as modelling and wedding photo sessions, were observed. Most participants interacted with the park's new theme, resulting in increased durations of walks, sitting, and photo-taking (Figure 6.21 and 6.22). Children were identified as the age group displaying the most enjoyment and interaction with the installation. The amphitheatre witnessed increased use during the installation event, particularly by families and couples. More social activities, such as children playing, communal activities and passive contact (listening and watching others), were observed. Despite the garden's new theme attracting and engaging the majority of visitors, some maintenance issues were reported, primarily due to the heavy usage of children's activities within the garden.

Figure.6.21 Crossrail Place roof garden visitor's activities during the magical installation inspired by the Jardin Majorelle in Marrakesh. source: Author, May 2021.

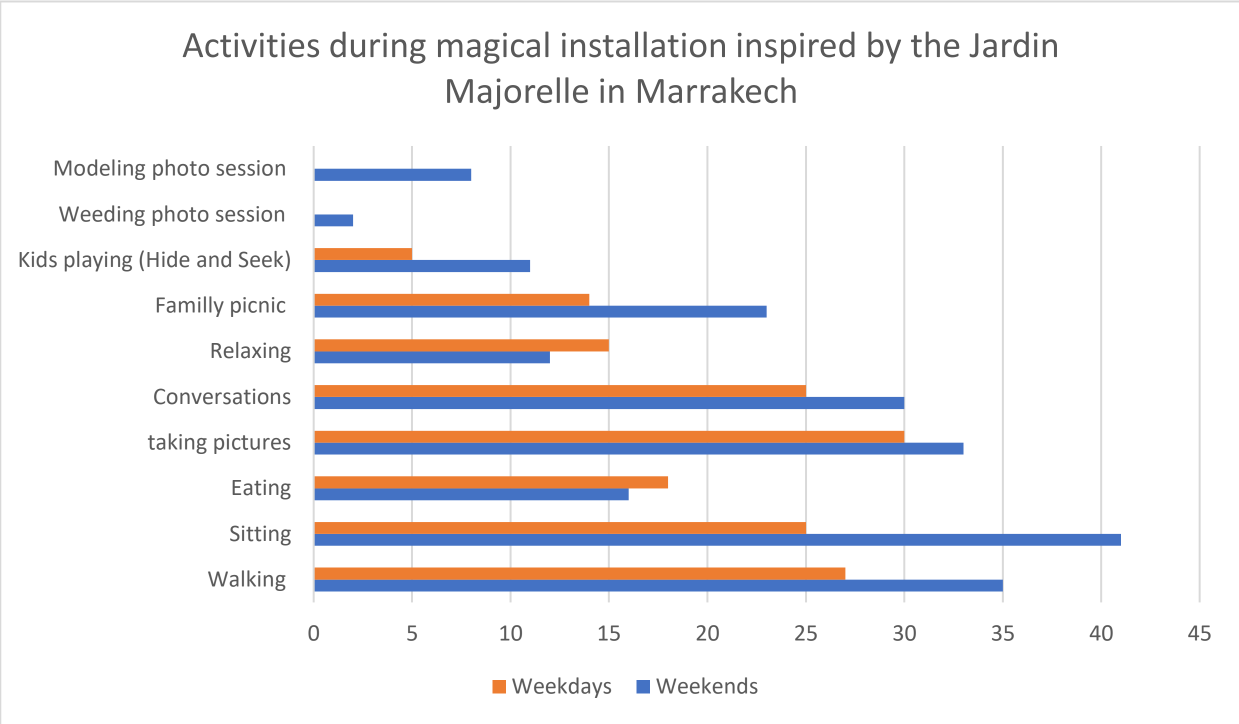


Figure.6.22 Bar graph for the average number of visitor's activities during the magical installation. Source: Author.

The post-pandemic data analysis offered an intriguing insight, demonstrating a conspicuous increase in both activity levels and garden utilisation, surpassing the metrics registered during the pre-pandemic era. This upturn in engagement is exemplified by the escalating popularity of the short story stations, which, over time, have become a mainstay of the garden, piquing interest, and drawing significant attention throughout the majority of the year. In this interactive setup, visitors are offered the liberty to select the duration of their chosen story - one, three, or five minutes - enabling them to tailor their experience to their preference. The dispenser then unfurls a mystery narrative for their perusal during their sojourn, as depicted in (Figure 6.23).

The summer of 2022 witnessed the garden branching out into the realm of cultural and artistic events with the inauguration of the amphitheatre for performances and music. Aptly named "Bloom", this free-ticket programme encompassed a diverse assortment of festivals, performances, and musical gatherings that breathed life into the amphitheatre. This effervescent array of events led to a record-setting influx of visitors, underscoring the triumph of the initiative. However, despite the resounding success of these events, an area warranting attention is the marked dip in the vibrancy and activity levels during regular weekdays compared to event periods. As evidenced by (Figure 6.24), the garden seemed somewhat less animated during non-event periods in contrast to the vibrant atmosphere during the pandemic period. This divergence invites a closer examination of potential strategies to foster sustained engagement and vibrancy during quieter, off-peak times.

Figure.6.23 Crossrail Place roof garden visitor's activities post-pandemic. Source: Author, July 2022.

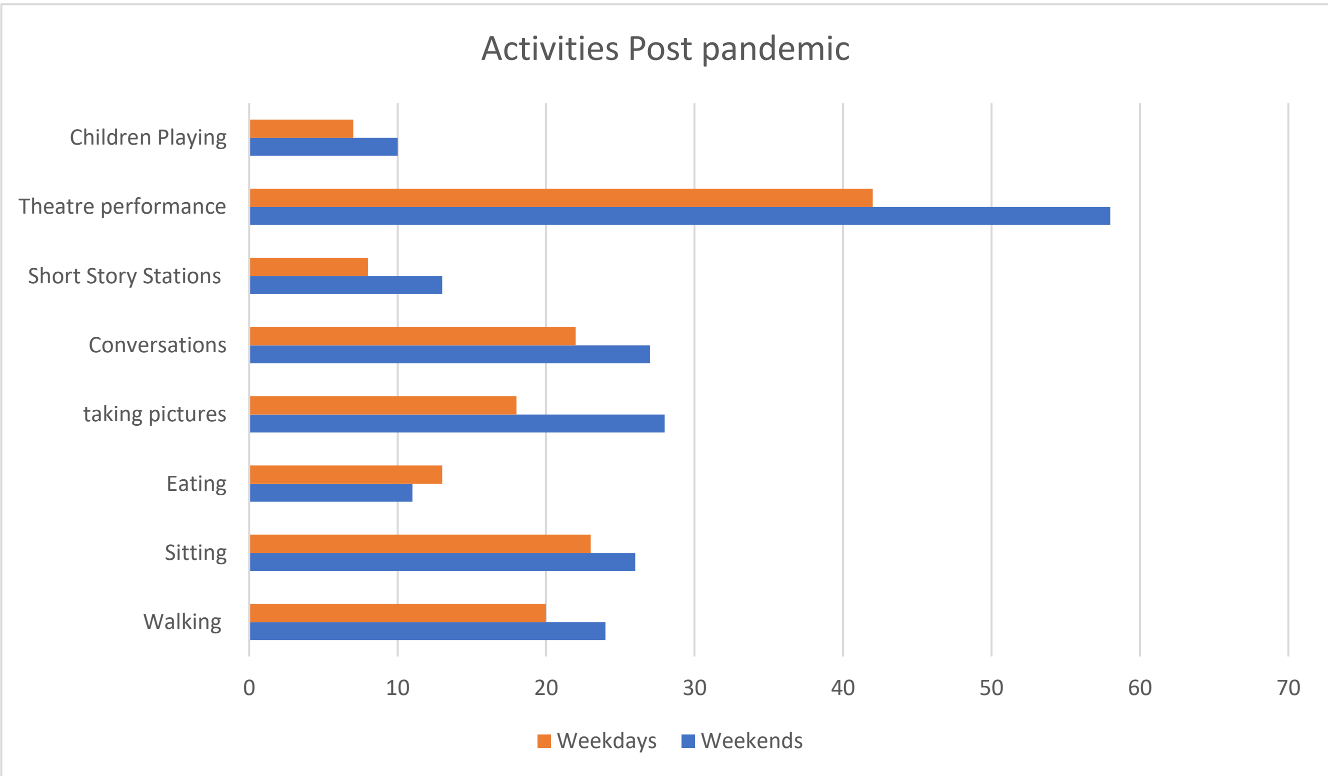


Figure.6.24 Bar graph for the average number of visitor's activities post pandemic. Source: Author.

6.3.2 Interview Results

In total, 33 comprehensive interviews were conducted at Crossrail Place in December 2021. The gender distribution was 45.4% (n=15) males and 54.5% (n=18) females, with an average age of the participants being 30.3 years. Regarding their residential or professional locale, approximately 60.6% (n=20) of the respondents either resided or worked in Canary Wharf, 24.2% (n=8) were inhabitants of other parts of London, and 15.1% (n=5) were short-term visitors to London, mainly tourists. The analysis of these interviews uncovered seven salient themes: the choice and the purpose of the visit, accessibility, safety with regard to COVID, territorial rights, activities, design concerns, and suggested design features and activities.

6.3.2.1 The Choice and the Purpose of the Visit

The main motivations for visiting the Crossrail Place Roof Garden, as mentioned by the interviewees, encompassed rest and meditation, meeting a friend, using the space for a lunch break, family picnics, and the fact that entrance is free of charge. A significant number of participants highlighted the frequently changing theme of the roof garden, relevant to different times of the year, as an appealing reason to visit the garden. The majority of participants reported being regular visitors to the garden, primarily owing to living or working within walking distance of Crossrail Place.

Numerous respondents, employed in Canary Wharf, divulged that they regularly utilise the garden during their lunch break. A few others credited social media as their primary source of awareness about the garden's existence. The typical duration of stay, as reported by most participants, did not exceed one hour. Prior to the interview, 68% of participants (n=22) had visited the Crossrail Place Roof Garden before. Of these, 36% were frequent visitors, frequenting the garden on a weekly basis, while 45% (n=15) reported visiting on a monthly basis.

One respondent, a 24-year-old female resident of Canary Wharf, conveyed that: *"This location holds a special place in our hearts. Living so close, we take pleasure in frequenting Crossrail Place almost daily. Our visits usually last around 30 minutes".* Similarly, another participant, a 28-year-old female who works in Canary Wharf, expressed, "*Although I don't reside nearby, I'd heard of this garden and was intrigued to explore it due to my workplace's proximity".* Regarding the discovery of the garden, a 26-year-old female resident of Canary Wharf explained that: "*Social media played a role - we discovered it on TikTok and thought it would be a lovely place to visit".*

6.3.2.2 Accessibility

When discussing accessibility to the roof garden, participants most commonly mentioned that while the garden is reachable from the ground level via escalators, its visibility from the street level is notably limited. A majority of first-time visitors expressed their dissatisfaction with the lack of clear visual access and connection from the street level to the garden (Figure 6.25). They shared that they often had to rely on posted signs or Google Maps to navigate their way up to the roof garden. Frequent mention was made of the garden's accessibility being facilitated by nearby public transport links, such as the Elizabeth Line (new name for Crossrail), the Jubilee tube line, and local bus stops. Upon analysis, most participants described the garden as accessible for individuals with special needs and those using wheelchairs, although a few criticisms were raised concerning the lift's location and its obstructed view of the surroundings.

A 30-year-old male living in London articulated that: *"The garden's visibility from the ground level was rather limited. The path to it was a bit confusing. Without knowing the place, one might need to resort to Google Maps. It does require a bit of a search."* Echoing this sentiment, a 28-year-old female from Canary Wharf expressed that: *"If you have Google Maps, it's slightly easier; but for a first-timer arriving from the train station or the bus stop, it can be a tad confusing as everything looks the same. You just need to be aware of your destination."*

A 74-year-old female living in London shared her experience with the lifts, stating that: *"We were slightly perplexed by the lift as it didn't appear to lead up here. Consequently, we took the escalators, which was fine for us, but it might inconvenience others."* Similarly, a 66-year-old female from London affirmed that: *"Having been here before, we knew to use the escalators to get here; otherwise, it might be slightly difficult for first-time visitors."*

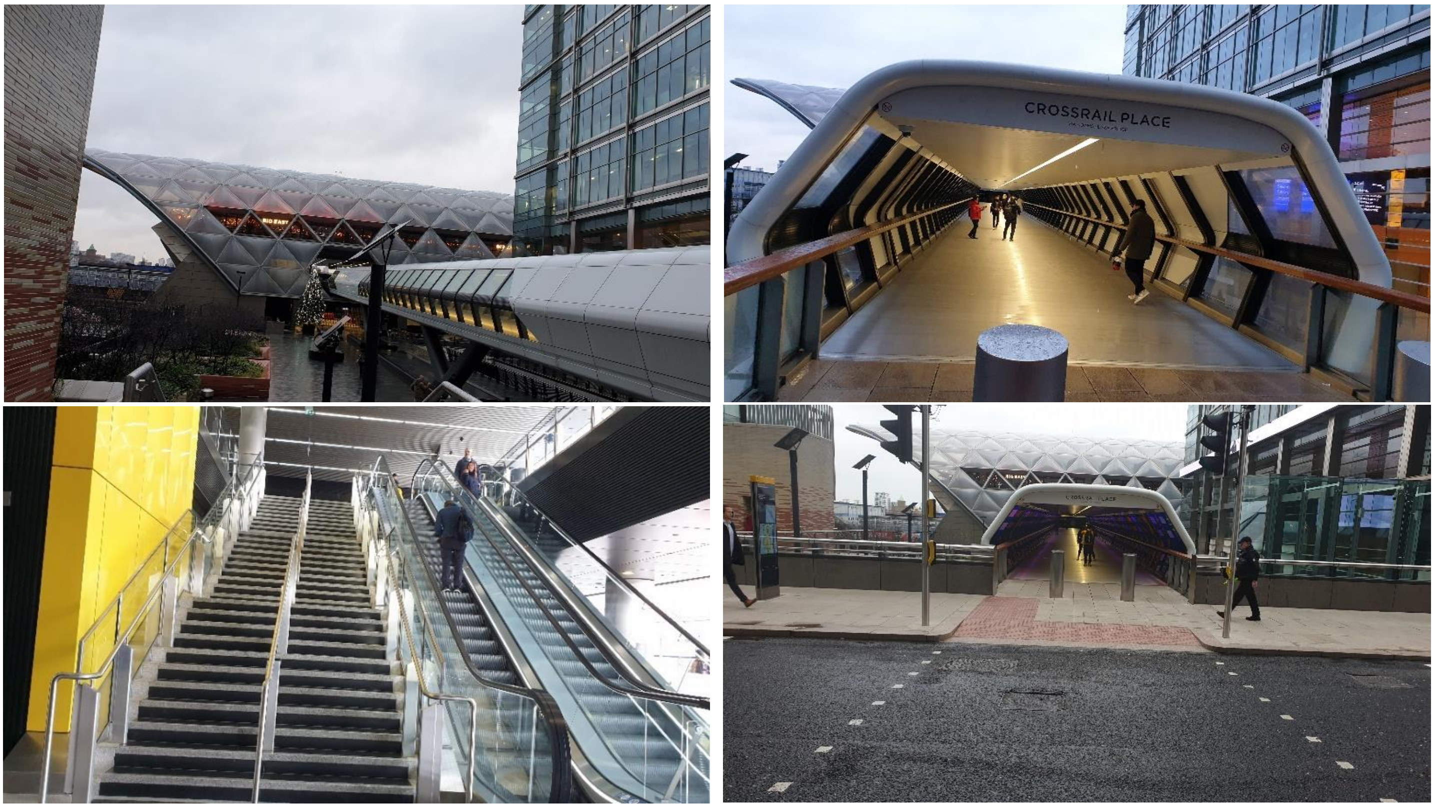


Figure.6.25 The Crossrail Place roof garden accessibility from the street level, source: Author, December 2019.

6.3.2.3 Circulation

Responses to the roof garden's circulation varied among participants. Most frequently, respondents indicated that the garden's curved pathways encouraged exploration and provided a sense of enclosure, fostering a deeper connection with the natural surroundings (Figure 6.26). Some participants noted the importance of walking paths being attractive, varied, and incorporating features such as shade and natural elements. However, the garden's curved paths were acknowledged as potentially confusing for first-time visitors. Commonly, participants expressed that the narrowness of the curved pathways could become an issue when accommodating both pedestrians and seated visitors. Those seated on the wooden benches reported a desire for increased privacy, stating that the close proximity of passers-by encroached on their personal space. For larger groups, these paths culminate in a small, amphitheatre-like space for gathering.

A 24-year-old female residing in London conveyed that: "*I appreciate the circulation here, and the curved paths enhance the garden-like feel*". Similarly, a 31-year-old male from Canary Wharf shared that: *"The circulation is interesting and far superior to linear and symmetrical systems. There's something inherently natural about curving around in a circular pattern and traversing the whole area".* A 28-year-old female from Canary Wharf also noted that: *"I think the circulation is good because it offers seating spots near the plants, although the walkways could be a bit wider".*

Figure.6.26 The Crossrail Place roof garden circulation (primary and secondary circulation) during the pandemic. Source: Author, October 2020.

6.3.2.4 Safety - COVID

The majority of participants (n=30) portrayed the Crossrail Place roof garden as a secure locale to visit amidst the COVID-19 pandemic. Respondents often noted the garden's open, well-ventilated nature, offering a sense of safety compared to other roof gardens in London (Figure 6.27). A significant number of participants (n=18) affirmed that visiting the garden during the pandemic positively impacted their mental wellbeing. An equally considerable number of respondents (n=21) expressed disappointment at the prospect of the roof garden's closure, with a consensus that such open spaces should remain accessible even in times of global crisis.

A substantial number of participants (n=28) underscored the demand for more open, well-ventilated roof gardens in London. They often stated that roof gardens hold a promising future in the city, although this requires strategic integration and governance by local authorities, rather than merely the private institutions managing the estate inclusive of public spaces.

Safety Considerations

A 66-year-old woman from London observed that: *"I feel safe here, even when walking around at night. I would feel comfortable until about 9 PM. The presence of numerous security cameras is reassuring".* A 32-year-old male tourist from France shared, *"Factors such as social distancing must be taken into account. In these times, some people might be uneasy about close proximity, but the well-ventilated nature of this space helps maintain an outdoor feel".*

Impact on Mental Wellbeing

A 35-year-old male, working in Canary Wharf, remarked that: *"Spaces like this contribute positively to physical and mental wellbeing during the pandemic. They offer a private, safe, green space for solitude".* A tourist from Spain, aged 26, echoed this sentiment: *"Being in a green space is comforting—it offers an escape from city life. Public roof gardens, particularly in metropolitan cities, are essential. I believe they have a positive future and contribute to the mental wellbeing of all users".*

The Future of Roof Gardens

A 74-year-old woman from London opined that: *"Given the ongoing loss of ground-level green spaces, roof gardens are likely to become more important. If the trend of urban development continues as it is, we may find roof gardens becoming a necessity rather than a luxury".* A 28-year-old woman from Canary Wharf added that: "*In the context of the pandemic, these spaces would certainly be advantageous. They offer a controlled environment compared to a public park. Here, visitor numbers and behaviours can be managed to ensure everyone's safety".*

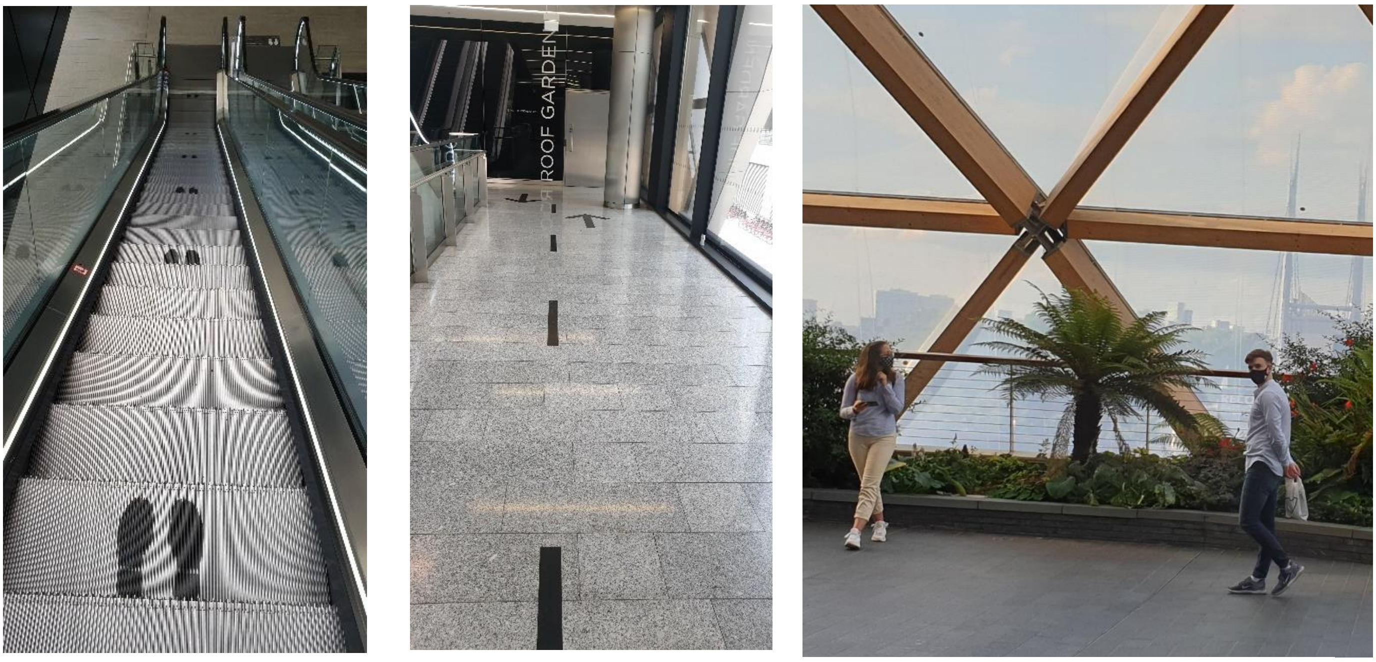


Figure.6.27 The Crossrail Place roof garden safety and social distancing rules during the COVID 19 pandemic. Source: Author, July 2020.

6.3.2.5 Territorial Rights

When participants were asked to reflect on their perceived level of territorial rights within the roof garden, compared to a genuine public park or public footpath with long-standing rights of access, responses were varied. A well-known issue in London and other British cities is the existence of seemingly public spaces which, in reality, are privately managed estates, such as the entire Canary Wharf district and the 'Freeports'. Rights of public access are heavily regulated in these areas. Sectors like hospitals, educational institutions, transportation hubs, business parks and shopping areas are instances of spaces accessible to the public, which, legally, are private estates.

A majority of participants (n=27 out of 33) recognised that the roof garden appears safer than most of London's public parks due to the enhanced level of security. Forty-one percent of respondents (n=14 out of 33) conceded that they were unaware of the roof garden's rules and restrictions, leading to ambiguity about whether it is a truly public space or a private one. This could suggest that the management has successfully avoided obtrusive notice boards.

However, a considerable number of participants (n=10 out of 33) acknowledged the garden as a private space, and raised concerns that they were unable to engage in certain activities typically associated with public parks (Figure 6.28). These participants perceived the roof garden as a tranquil, green haven for relaxation, albeit one that limits their freedom to partake in activities such as dog walking, picnicking, sleeping, photography, cycling, ball games, busking, lighting fires, skateboarding, and playing loud music.

Security Considerations

A 25-year-old woman from Canary Wharf stated that: *"This feels slightly different to a public park; it feels safer as you come here purposefully, while in a traditional park, many people merely pass through. It's quiet, but I feel very safe".* Another participant, a 27-year-old male from London, expressed, *"I think it's a safe place here, it's a nice safe area in general, that is safer than most parts of London. It is more restricted than a public space".*

Private Space Constraints

A 28-year-old woman from Canary Wharf observed that: *"I can't engage in the same activities as in a public park like Hyde Park. Picnics, sitting on the grass with my dog and listening to music aren't possible here".* A 66-year-old woman from London added that: *"Most people don't realise that this is private property. You can be accosted by security guards for taking photos. Most people aren't aware of the private property status and its associated rules".* A 26-year-old man from London expressed that: "*Initially, I wasn't sure if I needed to pay to enter. It appears more private than public. Better information provision would be beneficial*".

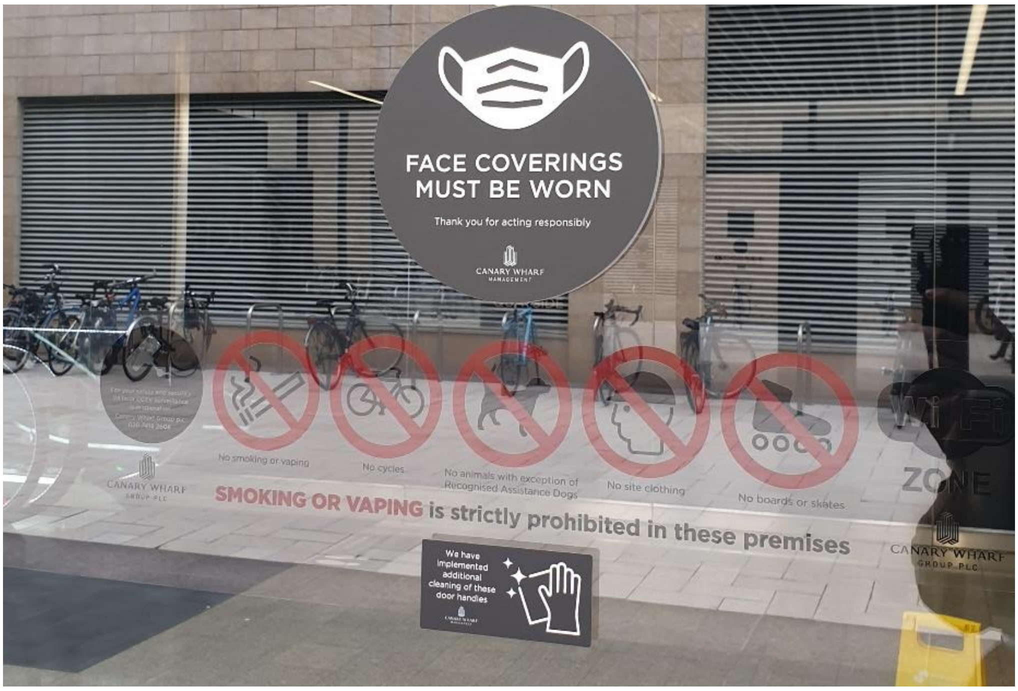


Figure.6.28 The Crossrail Place roof garden list of rules and restrictions. Source: Author, October 2020.

6.3.2.6 Activities

Participants revealed that they predominantly use the roof garden for walking, socialising, eating and drinking, capturing photographs, and relishing the verdant ambiance. As reported by the participants, their preferred activity within the roof garden was "sitting/relaxing in a safe and green environment." Particularly for those living or working in Canary Wharf, the roof garden holds significant value as an oasis for eating and relaxation during break times. This group further accentuated that the central location of the roof garden, surrounded by a plethora of restaurants, cafes, and pubs, adds to its appeal. Most families described the roof garden as a safe space for their children to play and romp about.

However, a subset of the participants (n=12 out of 33) expressed a desire for a greater variety of vibrant activities within the roof garden. A potential solution is illustrated by the author's photographs showcasing an array of colourful artworks, which provide a different user experience compared to a previous visit (Figure 6.29).

Reflecting on his experience, a 31-year-old male from Canary Wharf said that: *"If I was alone, I would probably get a book to read and eat lunch here."* A 25-year-old female from Canary Wharf shared a similar sentiment, stating that: *"I imagine if I worked in Canary Wharf, it would be really nice to come here for the lunch break."*

Highlighting the convenience of the garden's location, a couple remarked, "There's one good thing about this space, that it’s very centrally located, and if you're hungry there are plenty of cafes and restaurants around. So, if you're in the middle of Hyde Park, you would probably have to go a bit farther to grab food and drinks."

An interesting alternative activity was suggested by a 23-year-old male from Canary Wharf, who said that: *"I just relax and sit down, but if I'm allowed, I would like to do skateboarding here."*

Figure.6.29 The Crossrail Place roof garden visitors' activities during the pandemic. Source: Author, May 2021.

6.3.2.7 Design Concerns

Participants raised several design issues related to the roof garden that diminished their overall experience. Among the most frequently cited grievances were the absence of a shaded area to shield visitors from adverse weather conditions, such as winter rain and wind. Other concerns included the narrowness of the pathways, discomfort of the seating benches, poor visual accessibility, and a lack of opportunities for social interaction. A recurring issue raised by many participants was the unavailability of public restrooms at the roof garden level, which necessitates a trip to the ground floor.

However, not all feedback was negative. A 26-year-old female from Canary Wharf praised the diversity of the garden, stating that: *"We don't have concerns about the design, we liked everything. Every time we visit, we see a lot of new plants and themes from different parts of the world".*

Addressing the need for better protection against inclement weather, a 32-year-old man who works in Canary Wharf suggested that: *"They should have a shaded place for when it's raining, with seating spaces".* Highlighting another weather-related issue, a 65-year-old man from Canary Wharf noted that: *"It's a bit annoying when you think you can come here for lunch and you find the seats are all wet because of the rain and roof gaps".*

6.3.2.8 Suggested Activities and Design Features

Participants offered a plethora of suggestions for potential enhancements to the roof garden's design, as well as propositions for the introduction of new activities. Comfortable and mobile seating arrangements, a sheltered area for protection from precipitation, a water feature, broadening of the pathways, and the addition of more flora were frequently mentioned. Further suggestions encompassed the establishment of an outdoor café, a dedicated area for children's play, a pet-friendly zone, interactive night lighting, and an outdoor viewing platform overlooking Canary Wharf.

A considerable majority of participants (n=27, 81% of the interview sample) underscored the desirability of a water feature and a roof covering as key to ameliorating the garden design, particularly as a shield against the winter rains. In contrast, a notable subset of elderly participants (n=6, 18% of the interview sample) were content with the current design, perceiving no requirement for the introduction of further activities or new design elements.

Regarding elements that might foster social interaction, participants' responses varied. Popular suggestions included the organisation of events, the provision of interactive social seating areas, educational features elucidating the various plants, public art installations, games tables, and a koi pond. Several participants fondly recalled a public piano, which was removed during the pandemic, and suggested its reinstatement now that the necessity for sanitising each use has passed.

When queried on features that might encourage physical activity within the roof garden, frequently referenced suggestions included an increased variety of plants and flowers, the installation of fitness apparatus, yoga classes, table tennis tables, interactive night lighting pathways, and themed events. Walking emerged as the prevalent activity across all age groups, with numerous participants expressing comfort in allowing their children to run and play freely within the garden. Further suggestions included the introduction of sporting equipment, wider walking paths, organised events, and a dedicated children's play area.

Nonetheless, a segment of the participants, including a 74-year-old woman from London, expressed satisfaction with the present design, articulating that: *"I don't want them to add anything because there is enough space in Canary Wharf being taken away for other activities. Every time you come, there is less and less peaceful space in Canary Wharf, so I don't actually* *want them to add any children's activities or loud music or anything in the roof garden. If you want to do other stuff, there are other spaces."*

Features that encourage social activity

Participants put forth a variety of suggestions for features that could nurture a more social atmosphere in the roof garden. They expressed interest in seating arrangements that could facilitate dialogue, performances in the amphitheatre, and informative installations about the existing environment. Some also suggested the addition of water features to enrich the environment.

A 26-year-old female participant living in Canary Wharf suggested rethinking the seating configuration to promote a more social environment: *"I think some tables and chairs where you could actually sit with someone opposite them would create a more social atmosphere. Current bench seating makes the space feel less interactive and more isolating".* Another 28-year-old female participant from Canary Wharf expressed interest in performances: *"If the theatre is used for performances, that would be quite exciting. I am keen to see what they could do here, be it plays or musicals".*

Some participants also expressed a desire for more interactive and educational installations, such as informative signs about the flora and fauna in the garden. A 25-year-old female participant living in London expressed, *"...perhaps more features with which you can interact, such as reading spaces. For example, if there are statues with information that one could read about, it could be quite intriguing".* Adding a unique touch to the suggestions, a 27-year-old female participant from London said that: *"If they could add a fishing pond, that would be quite lovely. It would align with the overall design and ambience of the garden".*

Features that encourage physical activity

For features that would encourage physical activity in the roof garden, suggestions ranged from sports facilities and table tennis areas to the addition of distinctive architectural structures. The concept of using lights to transform the atmosphere was also proposed by a 30-year-old male participant from London: *"At night, it could be quite different - you could have lights on the trees, creating a unique environment."*

Another male participant, aged 31 and living in Canary Wharf, highlighted the need for exercise areas: *"The introduction of sports facilities, such as a calisthenics park, would be* *beneficial. I would like to exercise here".* Echoing the desire for more physical activity, a 24-year-old female participant from Canary Wharf suggested that: *"We would like to play table tennis here".* These responses highlight a collective desire among participants for a roof garden that supports social connectivity and encourages physical activity.

6.4 Chapter Summary

This chapter delivers a comprehensive analysis of two urban green spaces, the Sky Garden and the Crossrail Place Roof Garden, focusing on understanding user behaviours and the design changes during different pandemic phases: pre, during, and post. It further explores design elements and activities that can improve visitor experiences and stimulate social interaction and physical activities in roof garden environments. Observation studies and interviews at both sites furnish extensive insights into visitor demographics, visit durations, and activities across different pandemic stages. A salient finding is the need to cater to diverse visitor needs and preferences in the design and management of roof gardens.

Before the pandemic, the Sky Garden saw an average hourly occupancy of 310 and 260 visitors on weekends and weekdays respectively. Despite the primary activity being walking, the outdoor observation platform incited social interaction, mostly through photography. However, the pandemic introduced a significant decrease in occupancy levels due to social distancing measures. This situation also prompted a one-way circulation system that affected movement patterns and diluted the sense of publicness. The interviews involved 33 participants, revealing varying motivations for visiting the Sky Garden - from panoramic views and exploring London to meeting friends and the appeal of free admission. Although the outdoor terrace was popular for photography, several issues such as accessibility, online booking, security measures, and the design quality were raised. Proposed enhancements included adding more greenery, improving accessibility for the disabled, adding educational features, and promoting physical and social activities.

The Sky Garden study revealed visitors desired a relaxing environment for leisurely activities such as reading or working on a laptop. However, the high costs associated with the venue's food and beverages were a major deterrent. Other suggestions included a more varied plant collection with informational tags, guided tours, and other stimulating activities.

In contrast, the Crossrail Place Roof Garden participants expressed a desire for a garden encouraging social connectivity and physical activity. They suggested design features like live music events, musical instruments, photography opportunities, and 360-degree viewing platforms. Sports facilities, such as a calisthenics park and table tennis area, were also recommended to foster physical activity. Post-pandemic data demonstrated a considerable increase in activity levels and garden utilization, surpassing pre-pandemic metrics. The inclusion of short story stations and cultural events, such as the "Bloom" program, significantly contributed to this increase in engagement. This chapter also presents the results of the research on the current design and management of Crossrail Place, identifying crucial issues around vertical roof garden spaces and how these could change in a pandemic situation. Factors identified include accessibility, circulation, activities, suggested design features, visitor limitations, and social distancing. These findings have significant implications for the future design and need for vertical social spaces and roof gardens in London and signal a demand for further research in this field.

The two case studies provide unique insights. The Sky Garden visitors favoured a relaxing environment for leisurely activities while the Crossrail Place Roof Garden participants sought a space that promotes social connectivity and encourages physical activity. The pandemic impacted the two gardens differently: visitor numbers and duration of stay increased at the Crossrail Place Roof Garden with emerging activities such as reading, relaxing, and playing, while the Sky Garden experienced a decrease in visitor numbers with a post-pandemic preference for stationary activities.

The study's results have important implications for future design and need for vertical social spaces and roof gardens in cities like London, underscoring the importance of considering visitors' diverse needs and preferences. Key issues, such as accessibility, affordability, and the integration of activities that promote social interaction and physical activity, emerged as significant considerations for designing inclusive and welcoming roof gardens. These insights have implications for urban design practices, emphasizing the importance of creating environments that foster physical and mental well-being while promoting social interaction and a sense of publicness. A significant finding is that an immersive and interactive co-design process is essential for creating spaces that resonate with the visitors. In conclusion, the findings from the Sky Garden and Crossrail Place Roof Garden studies provide essential insights for the design and management of urban rooftop gardens. They stress the need for a more inclusive approach that takes into account the diverse needs of the public and for more collaborative design processes that leverage direct user feedback.

Chapter 7 (Results): Virtual Experience

7. Introduction

This chapter presents a qualitative analysis of a Virtual Reality (VR) laboratory experiment conducted to explore the comparative effectiveness of two methods and tools for creating interactive design models. The first model was developed using the Building Information Modelling (BIM) software "Autodesk Revit + Enscape", while the second model was designed using the game engine, "Unreal Engine". The research conducted a VR exploratory experiment followed by semi-structured interviews with 33 participants, none of whom were previously interviewed during the walk-along interviews study. This approach was adopted to eliminate potential biases from previous studies and observe any similarities and differences in participant responses.

The VR modelling depicted the existing conditions of two vertical social spaces, namely the Sky Garden and Crossrail Place roof garden. It aimed to investigate how VR and Visual Simulation (VS) technology can enhance the design experience of social spaces and foster community engagement. The primary goal was to study participant behavior and interaction within the virtual world and contrast these findings with a previous physical cognitive study discussed in Chapter Six. The secondary objective was to design and compare two advanced interactive immersive VR approaches - BIM and gamification, and assess their potential in improving public engagement in architectural design.

Analysis of the interviews revealed three major themes: virtual circulation, participant interaction, and interactive design. Eight sub-themes, depicted in Figure 7.1, emerged from these major themes, forming an initial structure for an interactive participatory design framework.

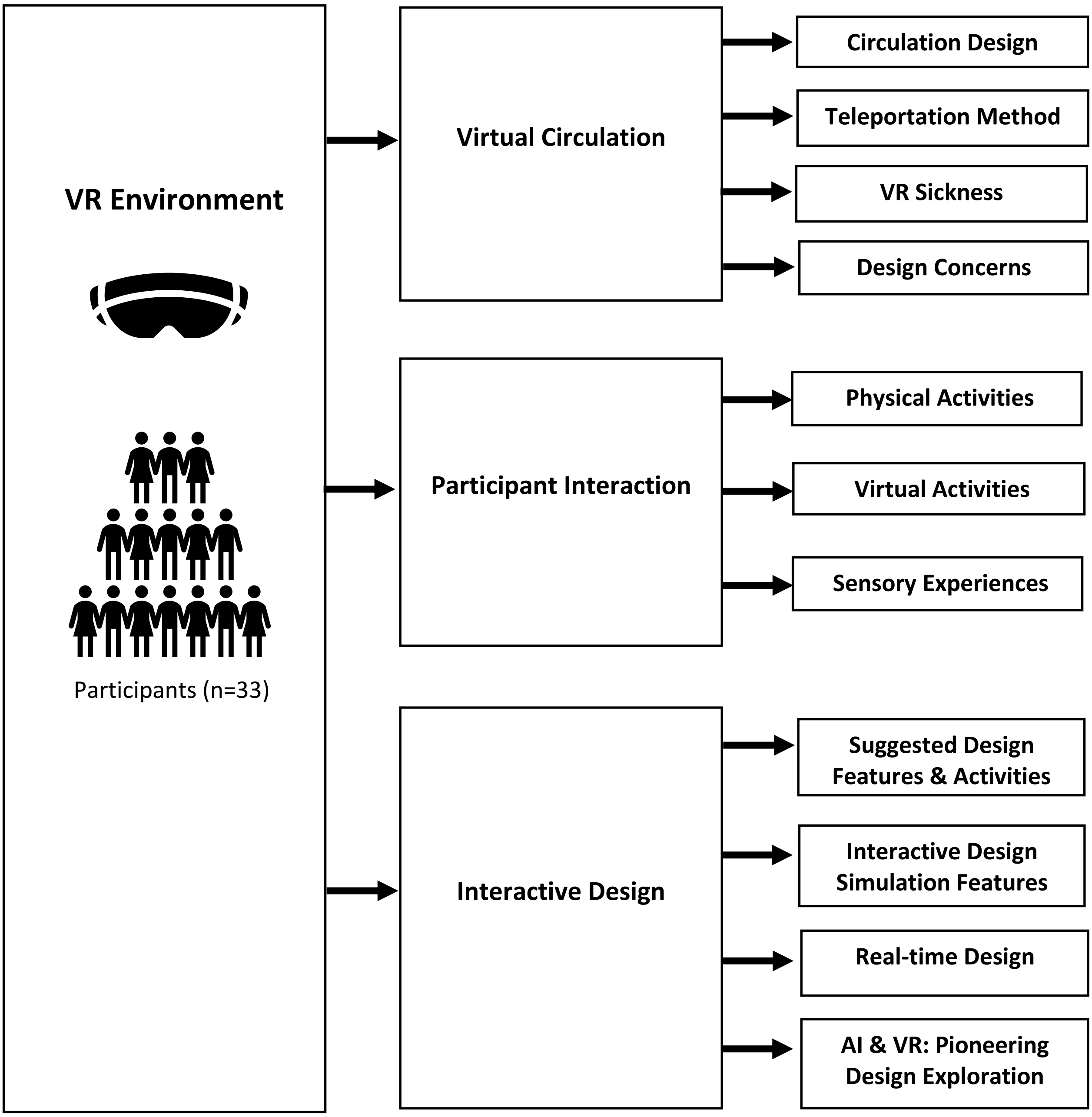


Figure.7.1 Framework displaying the main themes and subthemes for the VR experiment. Source: Author.

7.1 Circulation

This experiment adopted the virtual space circulation method as a means of direct observation, akin to a walk-along interview scenario. The participants embarked on virtual tours of both the Sky Garden and Crossrail Place, their physical movements, interactions, and teleportation within the virtual realm were recorded on video for subsequent analysis. The gathered data was then dissected and classified into three main sub-themes: space circulation designs, participant's design concerns about both gardens, and the comparative effectiveness of the different teleportation methods utilised by Unreal Engine and Enscape.

7.1.1 Space Circulation Design

Responses from participants regarding their preferences for circulation systems elicited a range of views. A significant proportion of respondents (n=20) expressed a preference for the Sky Garden's circulation due to its open floor plan, glass facade, and symmetrical layout. Such respondents characterised the circulation as 'open', 'inviting', 'linear', and 'direct'. Forty-five percent of participants (n=15) expressed acceptance of the one-way circulation system, implemented during the Covid era, viewing it as a necessary measure for safety and social distancing.

Among the participants who had not previously visited the Sky Garden (n=21), there was an expressed enjoyment of ascending the stairs in the virtual reality (VR) experience, appreciating that the Sky Garden is situated across three distinct levels (Figure 7.2). This aspect was reported to infuse the circulation experience with a sense of adventure, interactivity, and pleasure.

One participant, who had visited the Sky Garden in the past, stated that: *"Ascending the stairs to different levels evoked for me the sensation of a hike or mountain climb, presenting the opportunity to explore various platforms".*

An architect added that: *"I found the circulation in the Sky Garden easy to navigate and discover. Occasionally, the one-way system obliged me to move in a particular direction, which I found to be a simpler approach to reaching my destination".*

Moreover, this particular group of respondents pointed out a noteworthy limitation: the inaccessibility of the space for wheelchair users. They suggested the replacement of stairs with accessible ramps. In the actual Sky Garden, there is a lift servicing all three levels; however, it lacks the aesthetics of a glass, platform, or panoramic lift, thereby denying users the enjoyment derived from the upward motion typically experienced in a panoramic elevator within a large shopping complex. Yet, some architects contended that retrofitting the stairs with ramps or travellators could present significant challenges given the restricted footprint inherent to a tower design. They proposed the concept of a roll-on stair-platform-lift as a possible solution.

A landscape designer commented that: "*In the virtual realm, the circulation within the space appears clear and easy to navigate. However, the physical configuration of the stairs in the London Sky Garden might pose certain difficulties for individuals with special needs".*

A participant, who had not previously visited the Sky Garden, suggested that: *"In the Sky Garden, there ought to be certain elements made accessible for wheelchair users. These include aspects like circulation, the height of the bar, and furniture arrangement".*

A distinct group of participants (n=13) conveyed a preference for the circulation at Crossrail Place. They appreciated its curvilinear pathways and the sense of walking through a natural park, despite the absence of features such as pools, mini-hills, or footbridges. Participants used descriptors such as 'adventure', 'natural experience', 'exploration', and 'discovery' to articulate their experiences. Many, while interacting with the Crossrail Place model and teleporting throughout, noted that the curvilinear pathways could benefit from being widened to allow for better privacy for those seated on benches and to improve accessibility (Figure 7.2).

An interior designer noted that: *"With Crossrail Place, there is a sense of exploration and discovery akin to walking in a winter garden".* An urban designer similarly commented, "Crossrail Place engenders a sensation of sauntering through a forest or park. I found the pathways at Crossrail Place to be particularly intriguing".

Yet another participant, an urban designer who had not previously visited the Crossrail Place roof garden, remarked that: *"In Crossrail Place, I perceived the pathways to be somewhat narrow, potentially hindering movement. Overall, I am quite enamoured with the concept—the gardens and landscape features are truly impressive. On a personal level, I find the* *circulation in Crossrail Place more appealing, with the curves lending an element of adventure to the public space".*

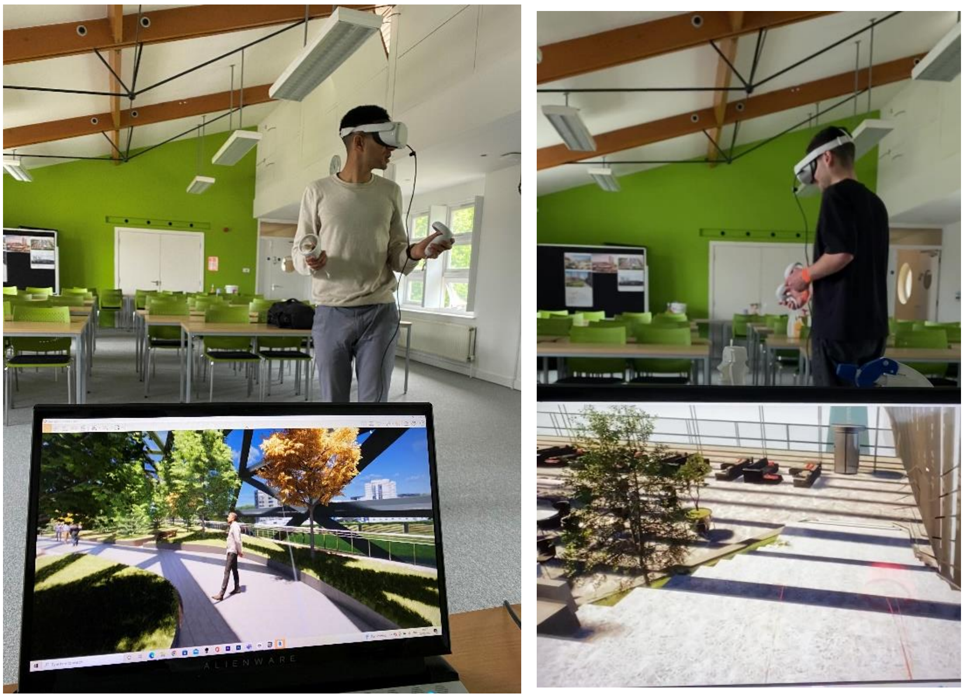


Figure.7.2 Participants teleporting and testing the space design circulation, source: Author.

7.1.2 Virtual Space Movement and Teleportation

The method of teleportation emerged as a significant sub-theme during the VR experiment. Participants experimented with two distinct teleportation methods to navigate the virtual environment. For the Sky Garden's virtual one-way circulation, participants utilised the Unreal Engine teleportation system. They were instructed to physically move within the safe 'guardian' area and use the **B** and **Y** controller buttons to teleport. For Crossrail Place, participants trialled the Enscape plugin teleportation method. This allowed them to walk physically within the safe 'guardian' area, teleport via the upper trigger button, and manoeuvre by pressing the trackpad of the left-hand controller.

One participant, who had previously visited both gardens physically, shared that: *"The virtual circulation gives an impression of physical presence within the space, particularly as you commence exploration".*

An architect commented that: *"The virtual circulation was user-friendly and intuitive. Despite being a 3D model, it maintains a realistic sense of scale and provides a comparable experience to the physical environment".*

Upon analysing the study's results, it was apparent that the two teleportation methods had distinct potential and limitations. 63.6% of the participants (n=21) expressed a preference for Enscape's teleportation, attributing their choice to its user-friendly interface, flexibility, smooth movement, and the various motion modes available, such as 'walk mode', 'seated mode', and 'flying mode' (Figure 7.3). Many participants noted that they enjoyed experimenting with the flying mode, a novel experience for most. However, some acknowledged a drawback of this teleportation method could be disorientation. A significant number of participants (n=9) reported feeling mildly dizzy when navigating by pressing the trackpads, especially when initiating flight.

A participant who had not previously physically visited either garden said that: *"I prefer the Enscape teleportation method as it allowed me to move freely and smoothly using the joystick. Moreover, it offered me a variety of options to try such as the seated, walking, and flying modes".*

An academic added that: "*Both methods have their merits. It's gratifying to navigate the space at eye level and then use the controllers to position oneself in different locations. But it was also pleasing to have a more imaginative mode such as flying, offering views from angles that are otherwise unachievable in real life. Although both methods are beneficial, I lean towards Enscape due to the greater range of options it provides".*

Contrary to the majority preference, twelve participants favoured the teleportation option provided by the Unreal Engine, viewing it as a superior simulation of a walking experience. The majority of participants (n=31) reported no symptoms of motion sickness while using this method, attributing this to its reliance on physical walking during teleportation (Figure 7.3). However, they expressed dissatisfaction with having to use the **B** and **Y** controllers for teleportation, as it detracted from the 'real walking' experience. The predominant limitation of this method, as identified by most participants, was its demand for substantial physical space in the laboratory, necessitating a large open area for a fully immersive walking experience.

A participant who had not physically visited either garden in the past mentioned that: *"I favour the Unreal Engine teleportation method, primarily due to the slight motion sickness effect I encountered with Enscape".*

An academic commented that: *"The Enscape teleportation method has a pitfall: moving with the joysticks is excessively slow, disrupting the virtual reality experience. In ordinary life, I don't move at such a slow pace, which made the experience feel more like a game than a physical immersion in a space. I found the Unreal Engine method to be more natural and swift".*

A landscape designer added that: *"The Unreal Engine method seemed quite realistic when I commenced walking and looking around. However, the experience lacked continuity because I had to press the controller repeatedly, which was disruptive. It didn't fully replicate a real walking experience unless there was ample space available for the experiment".*

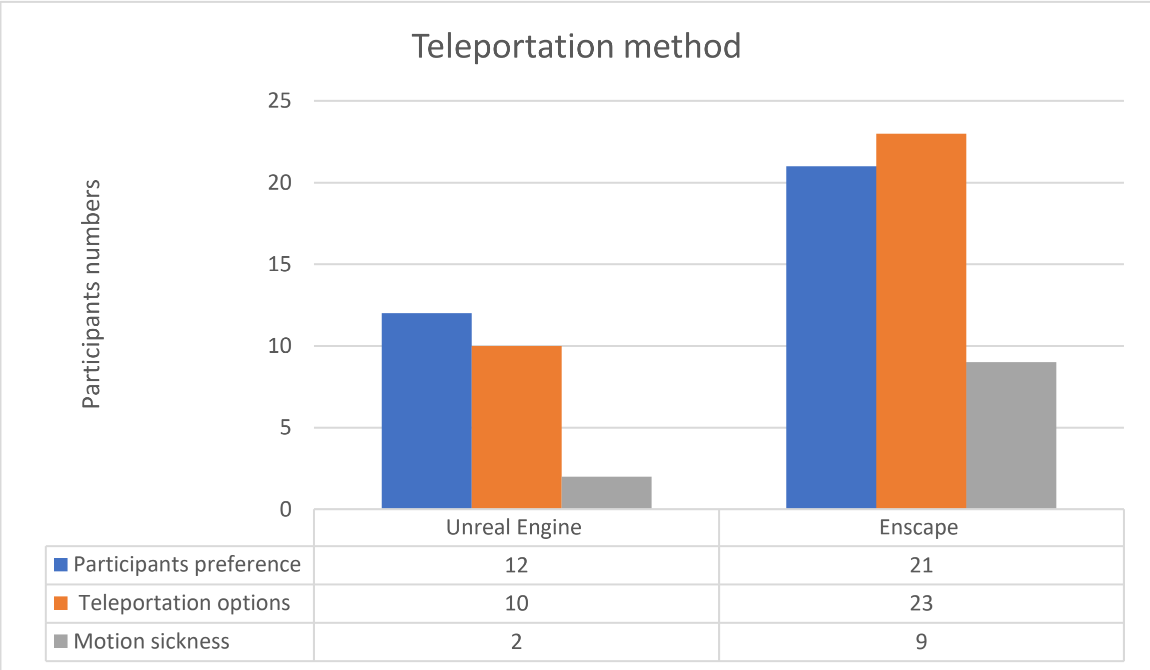


Figure.7.3 Graph chart for participants responses about the different teleportation methods used in the study, source: Author.

Additionally, the most favoured VR mode among participants (n=16) was walking, attributable to the human-scale and steady pace of movement it provided for exploring the environment (Figure 7.4 and 7.5). Walking is known to have mental and physical health benefits in real life, whereas teleportation, while convenient and enjoyable, does not mirror authentic human experience. During the interviews, a significant number of participants (n=9) suggested that a treadmill might be a practical solution for movement in VR, particularly when physical space is constrained. While omnidirectional treadmills exist and could provide an intriguing experience for participants, their high cost and the training required to operate the equipment pose significant challenges.

A game designer noted that: *“I favour movement over sitting stationary. The idea of a VR treadmill is appealing, as it not only benefits physical health but also aids in reducing symptoms of VR sickness”.*

A considerable number of participants (n=13) expressed a preference for a hybrid mode, which would afford them the flexibility to choose between walking and teleporting during the garden space experience (Figure 7.5). The seated VR experience was generally favoured by the older age group, who described it as the 'safest' and 'most convenient' method of exploring the virtual environment (Figure 7.4 and 7.5).

A participant who had previously visited both gardens physically expressed that: *“I prefer a hybrid mode. I enjoy the ability to physically walk around while also having the freedom to utilise the controllers for teleportation".*

Figure.7.4 Participants testing different VR modes, source: Author.

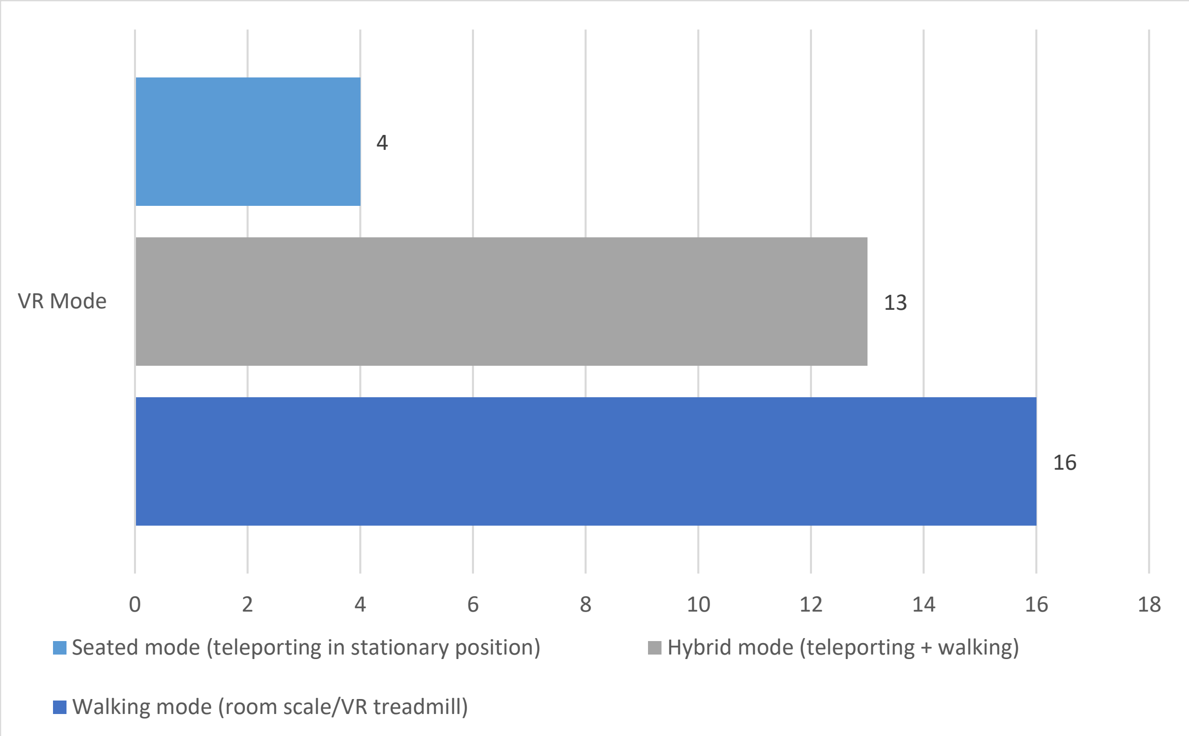


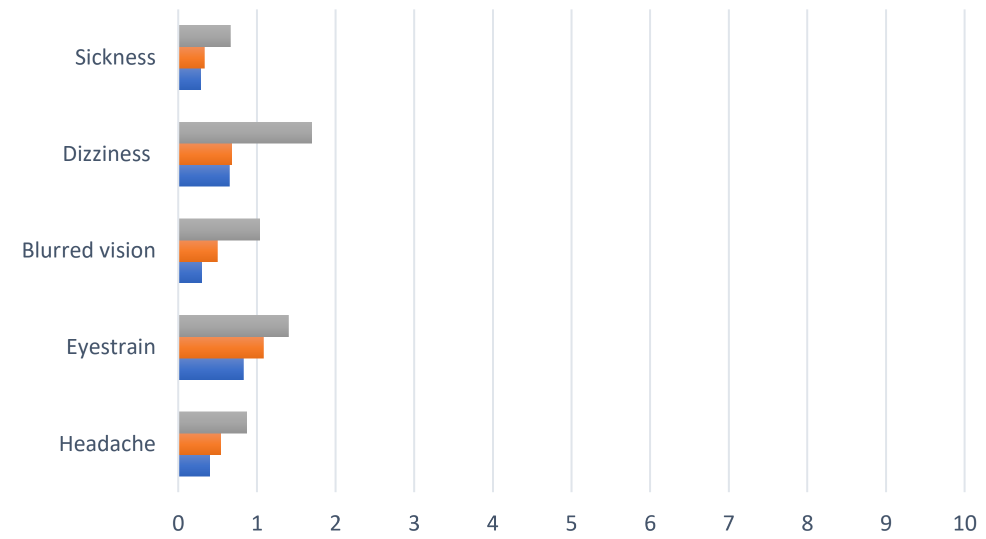
Figure.7.5 Graph chart for participants VR mode preferences, source: Author.

7.1.3 VR Sickness

The study indicated that occurrences of motion sickness might be mitigated by limiting the duration of VR usage to a maximum of 20 minutes and incorporating intermittent breaks during the exercises. Furthermore, a hybrid teleportation method could foster a sense of safety for participants as they navigate the virtual environment. Experimental results revealed a minor increase in discomfort symptoms such as headache, eyestrain, blurred vision, dizziness, and general malaise during the testing of both teleportation systems.

This marginal but noteworthy increase was carefully documented and is visualised in the subsequent diagram (Figure 7.6). It is seen that the majority of the symptoms saw a marginal escalation during the first phase of the experiment with the Sky Garden VR model. This gradual intensification of symptoms persisted through the second phase, which involved the Crossrail Place VR model. Remarkably, it was during the Crossrail Place experiment that the most substantial increase in the incidence of dizziness was recorded. This notable surge in discomfort can be attributed to the excessive use of the flying mode available in Enscape, which was utilised by a considerable number of participants.

It is worth noting that while VR provides a unique and immersive experience, these findings underscore the importance of balancing usage to avoid discomfort. Therefore, careful consideration must be given to the length of exposure and choice of movement modes in virtual environments.



	Headache	Eyestrain	Blurred vision	Dizziness	Sickness
After the Crossrail Place experiment	0.87	1.4	1.04	1.7	0.66
After the Sky Garden experiment	0.54	1.08	0.5	0.68	0.33
Before the experiment	0.4	0.83	0.3	0.65	0.29

Figure 7.6 Graph chart for the participant's average personal comfort before and after the study. Source: Author.

7.1.4 Design Concerns

A majority of participants (n=30) consistently identified the virtual circulation method as a potent tool for highlighting their design apprehensions concerning the designs of both gardens. Participants expressed that the ability to teleport and walk virtually within the space offered them a detailed perspective of diverse design aspects, including a sense of scale, lighting, materials, and furniture organisation. Intriguingly, this approach prompted a significant number of participants, who lacked a background in architectural design, to articulate their perceived design limitations and engage with the space, even offering opportunities to experiment with and test their ideas in real-time. This aspect of participant interaction with design will be delved into more deeply in the subsequent interactive design section.

When focusing on the design of the Sky Garden, a significant number of participants (n=26) began to pinpoint their constraints and concerns (Figure 7.7). The analysis underscored a shared critique among two distinct participant groups: those who had been previously interviewed at the Sky Garden, and the VR experiment participants who had not physically visited it (Table 7.1). Predominantly, these design concerns revolved around the need for increased green areas and public seating spaces adjacent to plants, the reorganisation of seating areas to enhance privacy, allow for social distancing, and improve accessibility. Further design issues raised pertained to the aesthetics and material choices in the restaurant and outdoor viewing platform, hinting at a need for reconsideration in these areas.

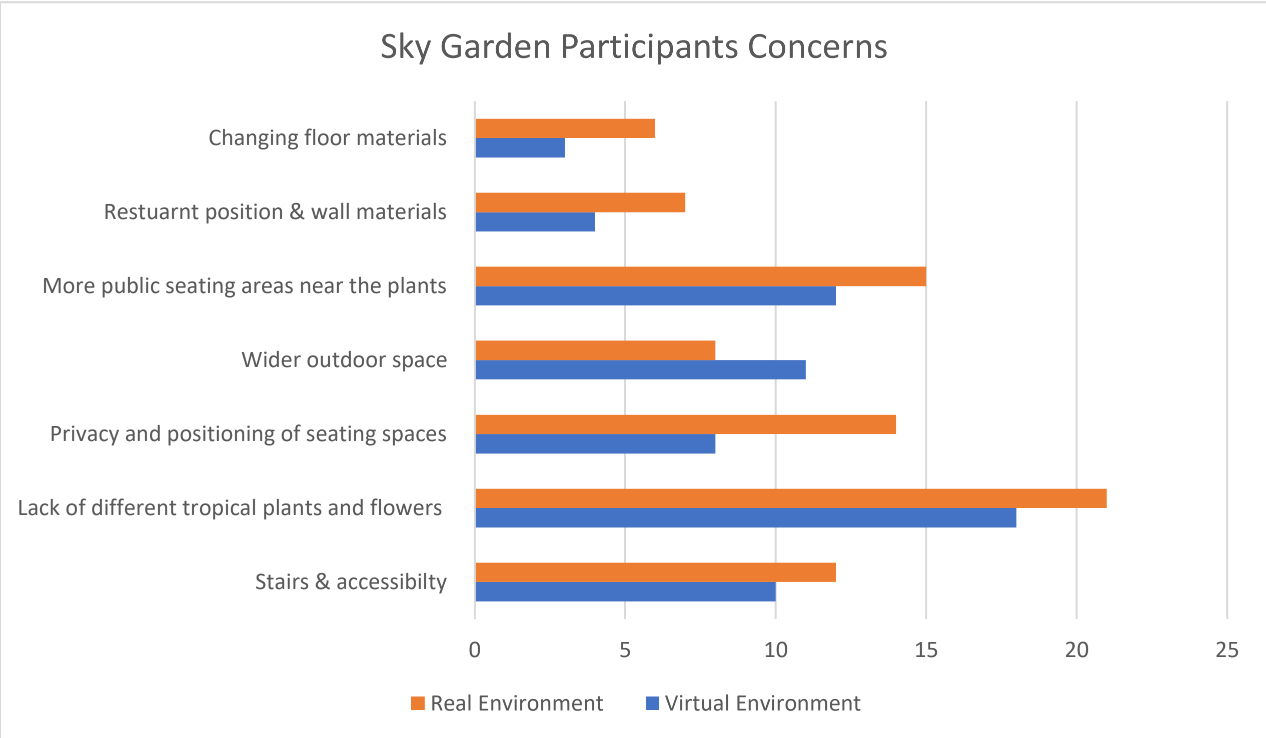


Figure 7.7 Bar chart illustrating the number of participants' concerns (out of a maximum of 33) in both the real and virtual environments of the Sky Garden. Source: Author.

Table 7.1: Comparative Design Concerns between Physical and Virtual Participants in Sky Garden (Source: Author)

Design Concerns	Participants: previously interviewed at the Sky Garden in London	Participants: not been to the Sky Garden (interviewed during the VR experiment)
Public seating	*"It will be nice to provide more seating spaces for everyone and not only for people who are ordering food and drinks".*	*"I think having more public seating spaces like benches or stair seating near the plants could make people feel more comfortable sitting without feeling forced to order food or drinks".*
Seating areas organization	*"Despite the thing we are having right now because of COVID-19, I need more private seating areas. The seating spaces are comfortable but very close to each other. They need to be well designed and placed to maintain social distancing and privacy".*	*"I also think it will be awkward having to share the sofa with strangers. If I am physically in the space, I will choose to sit on one of the chairs near the plants".*
Plants and green spaces	*"I think with the name itself Sky Garden, I would like to see a different kinds of flowers and roses. If they can add more green features, it will differently encourage more people to come and visit, not only for the view".*	*"With the name 'garden', you are expecting to see more natural plants. It would be nice to add more green space and a bit more flowers".*
Outdoor terrace	*"The terrace was restricted with a certain number of people, so the garden might need a more open space for people".*	*"I think maybe an open space, so instead of being in an indoor environment all the time, it may be a bigger outdoor area".*
Restaurant design	*"I think that the restaurant in the middle is like blocking out most of the view; you have to go around it to see most of the city views and landmarks".*	*"I don't like the design and the position of the restaurant in the middle of the space I think it needs to be more open and the higher you go up the better view you would get; and for the restaurant design it would be better if it's all glass and transparent so even people inside could enjoy the view".*
Accessibility	*"I don't know how it would work if you were handicapped in any way, or if you have a disability. A lot of the garden experience is on the stairs so you wouldn't be able to see any of that if you are taking the elevator".*	*"I always care about people with wheelchairs or old people. I didn't see any ramps in the roof gardens. You could do a hybrid: blend ramps and stairs together, and it will be both statically and functionally so good".*

A substantial segment of participants (n=18) expressed a preference for the design of Crossrail Place as a Vertical Garden (VG), attributing their preference to its verdant character and distinctive landscape features. They depicted the roof garden as notably 'more public' than the Sky Garden. However, participants also raised several design concerns that merit consideration (Figure 7.8). For instance, there was a consensus on the need for more comfortable and sociable seating arrangements as opposed to the existing wooden benches. They also highlighted the necessity for wider pathways to enhance privacy and accessibility, and the inclusion of a greater variety of plants and flowers to enrich the garden's appeal.

Moreover, a significant number of participants (n=22) advocated for a more interactive design that incorporates public art and statues, an outdoor viewing platform, a water fountain, a pet-friendly zone for dogs, and an outdoor bar and café. These features, they argued, would bolster the garden's appeal and improve its functionality.

One academic participant shared that: *"In the Crossrail Place roof garden, I would envisage more sociable seating arrangements where people could converse face-to-face or in a circular formation. Additionally, incorporating some tables and a pet-friendly area for dogs would also be advantageous".*

Another participant, who had visited Crossrail Place in the past, opined that: *"The design of the space was largely satisfactory, and it resonated closely with my personal experience when I visited in person. There was no substantial discrepancy. However, I believe the roof garden could benefit from more comfortable seating options for extended periods. Instead of only wooden benches, I would suggest the addition of movable chairs and pergolas to enhance comfort and flexibility".*

In conclusion, participants in both the real environment and the VR experiment identified various design concerns and limitations in the Sky Garden and Crossrail Place gardens, illustrating the similarities between the physical and virtual worlds. The virtual circulation method effectively simulated the real environment experience, enabling participants to provide valuable feedback for potential improvements.

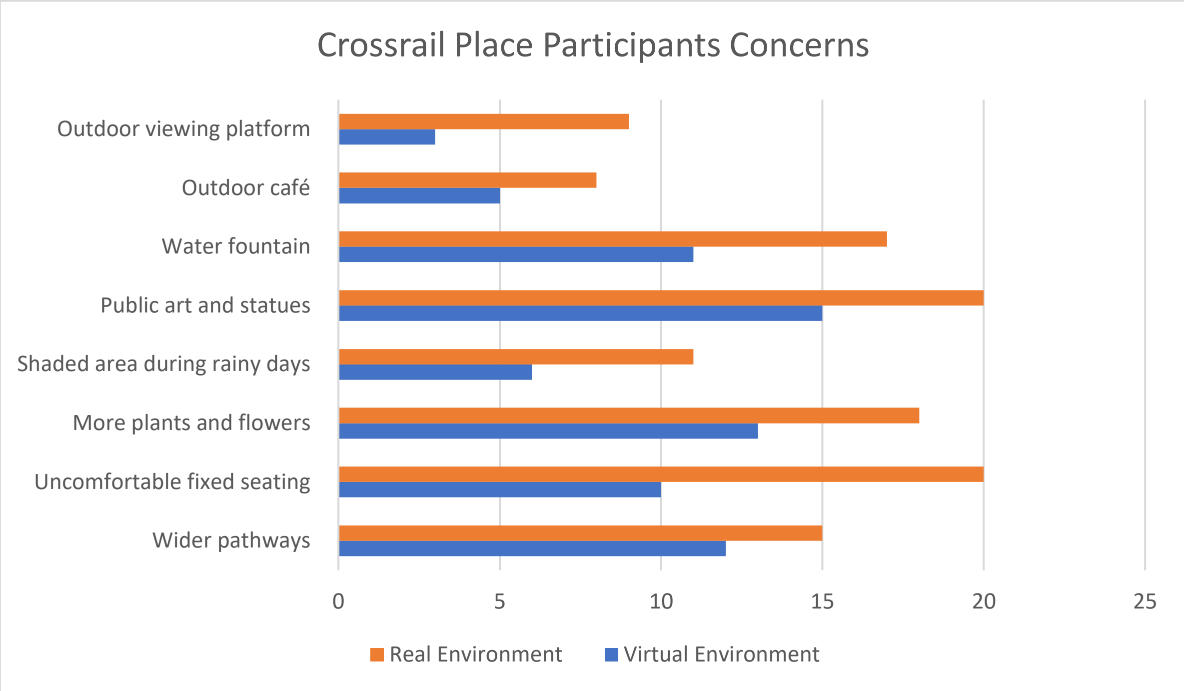


Figure 7.8 Bar chart illustrating the number of participants' concerns (out of a maximum of 33) in both the real and virtual environments of the Crossrail Place. Source Author.

7.2 Participant interaction

The overarching theme of 'Participant Interaction' provides a detailed exploration into the manifold ways in which participants engage with both physical and virtual environments, namely the Sky Garden and Crossrail Place. Through meticulous analysis of observed behaviours, this theme elucidates the complex interplay between individuals and their surroundings. This theme further branches into two distinct subthemes, firstly, the 'Activities' participants partake in during their visits, and secondly, the 'Sensory Experiences and Emotional Responses' elicited during these interactions.

7.2.1 Activities

Participants were invited to speculate on the activities they would likely engage in upon visiting the Sky Garden. A substantial proportion (n=30) outlined 'appreciating the city views', 'partaking in refreshments', 'dining', 'socialising with friends', and 'capturing photographic memories'. Contrastingly, within the Crossrail Place environment, dominant activities were oriented towards 'relaxation', 'admiring the flora and natural surroundings', 'reading', 'having a meal', and 'photography'.

A notable proposition from several participants was the concept of issuing complimentary virtual access to prospective visitors who may be geographically or otherwise constrained from physically attending these spaces. The hypothesis suggested that such a virtual exploration could ignite further curiosity and consequently stimulate a greater influx of physical visitors. Importantly, a significant proportion (n=18) of the participant group who had not previously had the opportunity to visit either of the gardens in person reported that the VR experiment had effectively piqued their interest in planning a physical visit to the gardens.

A participant voiced their support for this approach, articulating, "It's an advantageous experience, being able to navigate these spaces in a virtual environment prior to planning a physical visit. This preliminary exploration can assist in determining whether the space will resonate with one's preferences".

Another participant expanded on the potential utility of this technique, positing, "The ability to trial the environment is an efficacious approach. If there are intentions to host exhibitions or other events in the space, having the facility to construct a digital mock-up prior to committing significant resources can be highly beneficial. Additionally, the opportunity to involve a wider population in testing the space can yield invaluable user feedback".

7.2.2 Sensory Experiences and Emotional Responses

A substantial number of participants expressed that the exploration of the virtual environment imbued them with heightened confidence and freedom to engage in an array of physical and virtual activities, some of which are unattainable in real-life settings. These include jumping, flying, dancing, running, and sitting on the ground. These physical interactions were conspicuous during the experiment, with several participants attempting to interact with various elements of the environment, such as exploring different textures and interacting with landscape features like trees and plants (Figure 7.9).

It was frequently noted by participants that the virtual reality (VR) experience stimulated their senses, prompting them to interact with various design features and objects within the space. This method fostered a deeper understanding of their personal utilisation and requirements within the environment. Furthermore, it sparked their creativity, enabling them to envision new design scenarios. However, the absence of tactile sensation, air movement, and olfactory stimuli were identified as major hindrances to a fully immersive VR experience.

One landscape designer relayed their enjoyment of the flying mode, stating, "It enables me to explore the roof garden and analyse the space design from diverse perspectives, such as the human-eye perspective and the bird's-eye perspective".

An academic participant highlighted the exceptional opportunities that VR presents, stating, "Virtual Reality offers fantastical possibilities. For instance, I can fly, penetrate the ground, stand on a sofa - I can engage in activities that are impossible in the real world. When these diverse elements come together, there is no room for regulated behaviour".

A participant who hadn't previously visited either of the gardens in a physical capacity expressed a desire for tactile interaction, saying, "I yearn for the ability to touch the materials. For instance, I would like to feel the texture of the leather chair. Some elements may appear visually appealing, but lack comfort upon use".

Figure. 7.9 Participants' interactions in the virtual space. Source: Author, video link: https://www.youtube.com/watch?v=e7K0kvvoHDw&t=145s.

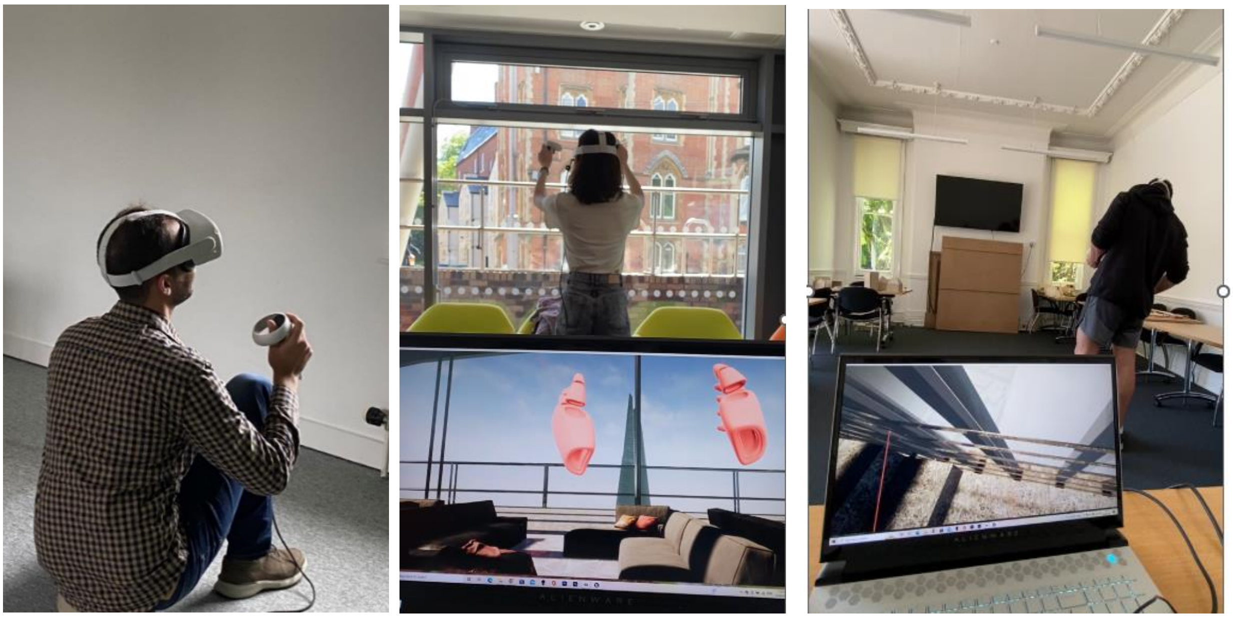


Figure.7.9 Participants interactions in the virtual space, source: Author.

A majority of participants (n=29) frequently articulated a sense of isolation within the virtual space, expressing a preference for shared experiences with other individuals such as friends, family, and the general public. Observing the behaviour and interactions of others in public spaces was commonly reported as a primary interest; the participants found engagement in observing the static human models within the Crossrail Place environment (Figure 7.10 and 7.11).

In addition, several participants proposed alternative social activities within the virtual spaces, such as hosting online gatherings, meetings, webinars, and utilising the environment as a social platform. A subset of participants, perhaps those familiar with interactive 3D world simulations like Second Life and Decentraland, envisaged a greater degree of interactivity within these gardens, such as engaging in conversations, partaking in games (table tennis, pool, chess), or collectively watching films.

A significant minority (n=8) of participants recalled their experiences during the 2020 lockdown, emphasising the potential utility of VR as a social online platform in the face of future pandemics. Nevertheless, the group concurred that socialising within a virtual green environment would not replicate the richness of physical, cognitive experience. However, they conjectured that it could have a positive impact on the mental wellbeing of individuals living in isolation during such crises.

An academic participant observed that: *"Observing the static human models in the Crossrail Place model was enjoyable. In urban public spaces, a substantial part of the experience is observing others. I found myself replicating this behaviour virtually. This mirrors real-life experiences in public urban spaces where people-watching is a common activity".*

Another academic, an expert in VR, expressed that: *"I would desire a shared experience in these spaces, similar to how I would enjoy the real environment with others. Although we are yet to reach a stage where a virtual coffee or shared dining experience is possible in VR".*

One participant who had physically visited both gardens previously, remarked that: *"Considering the mental health implications during lockdown, VR could make a significant difference, particularly for those living alone. It's an element that can foster happiness and positively influence individuals' moods when used for socialisation".*

Finally, a participant unfamiliar with both gardens in reality, but working as a psychiatrist, suggested that: *"If I were to apply this VR experience to my professional life, it's considerably more engaging than standard online meetings, particularly for individuals dealing with mental health issues. I value the idea of these spaces serving as a social VR platform".*

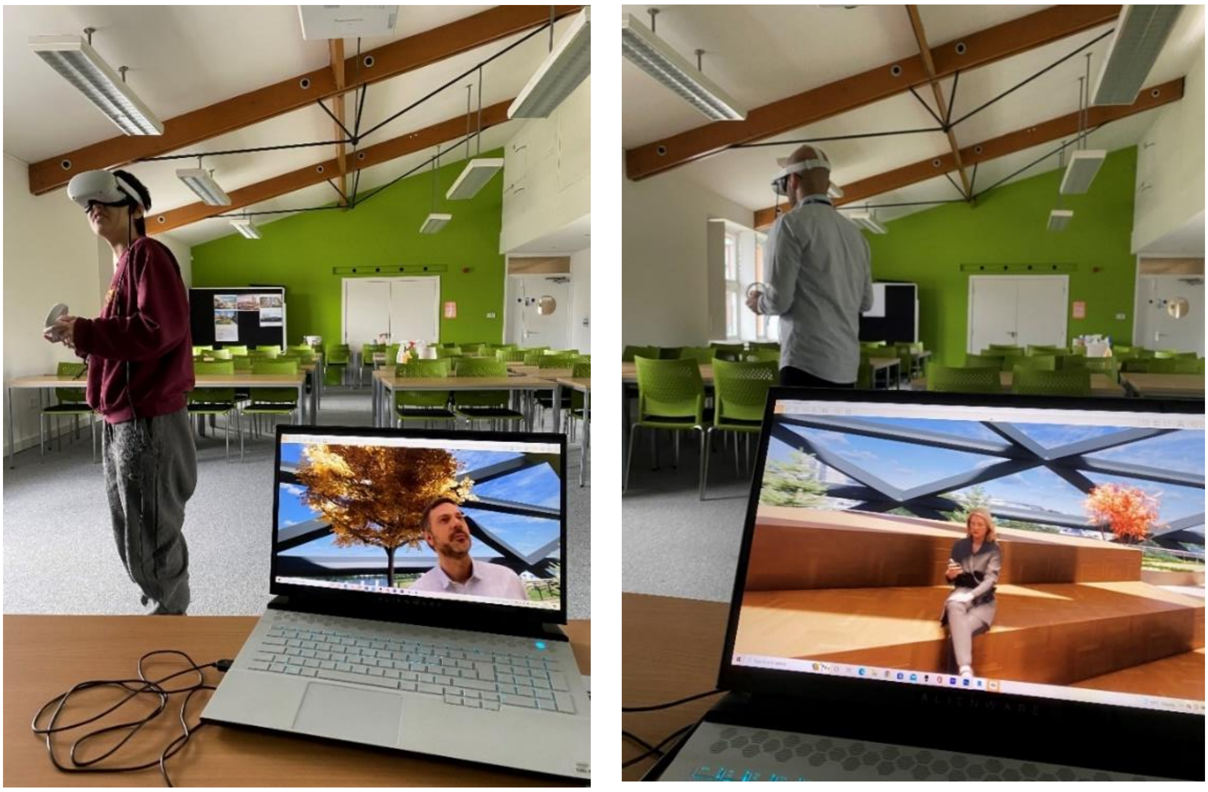


Figure.7.10 Participants interactions in the virtual space, watching others and trying to touch objects. Source: Author.

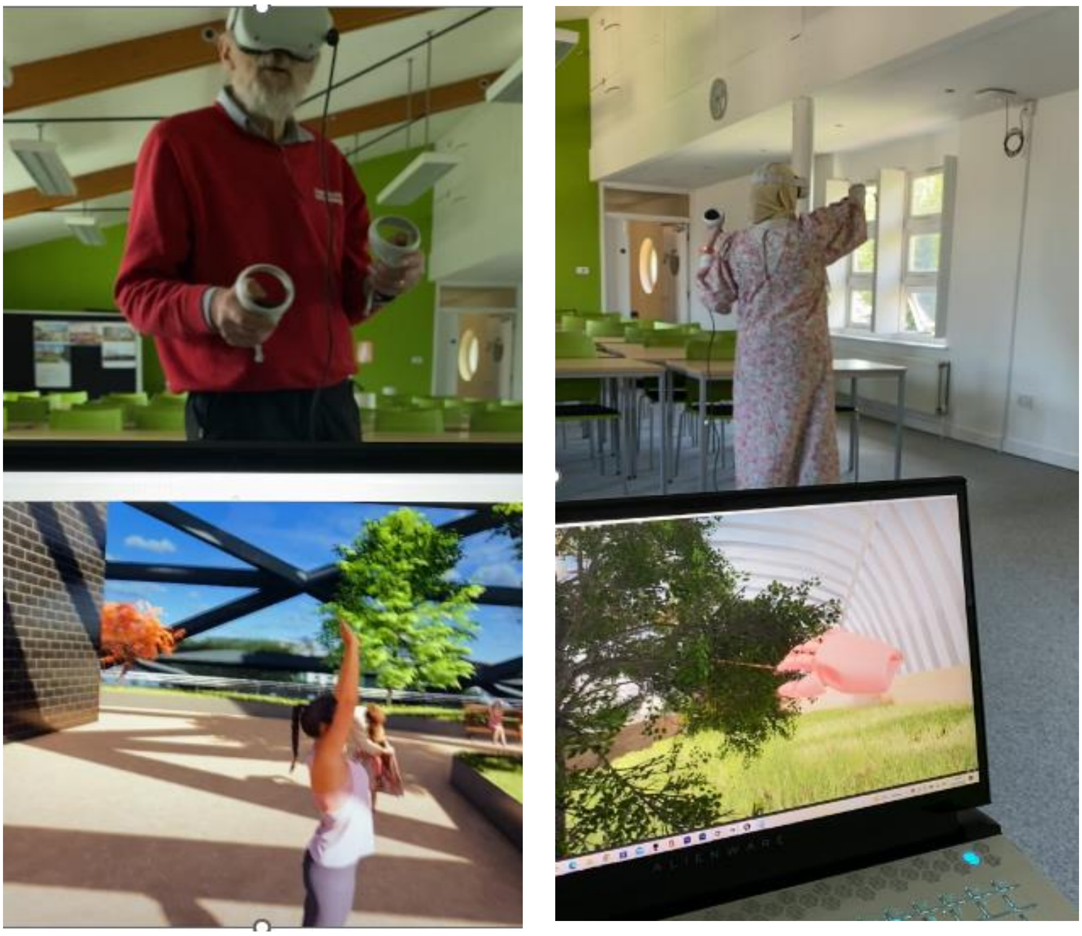


Figure.7.11 Participants interact in the virtual space, watching others and trying to touch objects. Source: Author.

7.3 Interactive Design

Interactive design emerged as a salient and engrossing theme among the participants. Unanimously, all participants (n = 33) were in concurrence that the application of novel tools and features could markedly enhance their discernment of design quality across the two case studies under consideration. A significant cohort (n = 28) of participants contended that the utilisation of such instruments in the architectural design process could effectively involve end-users in the visualisation and refining of complex facets of a project. Further, such interaction enables users to comprehend and tackle specific design challenges, thus enabling them to adjust the design and assess the space's utility based on individual requirements and preferred activities (Figure 7.12).

Utilising the capabilities of the Unreal Engine platform, the researcher constructed interactive virtual reality environments by implementing the Blueprints visual scripting method. This approach allowed for a range of interactive features such as real-time material modifications, with numerous interactive materials being integrated into elements of the Sky Garden, such as floors, bars, chairs, and walls, allowing participants to select and adapt these elements as they saw fit. Additional interactive components made possible by the Unreal Engine included X-ray functionality, object manipulation, virtual annotations, and virtual camera functionality. In contrast, Enscape, while offering features such as light simulation and screenshot rendering, limits the degree of participant control in terms of design alterations, including objects and materials.

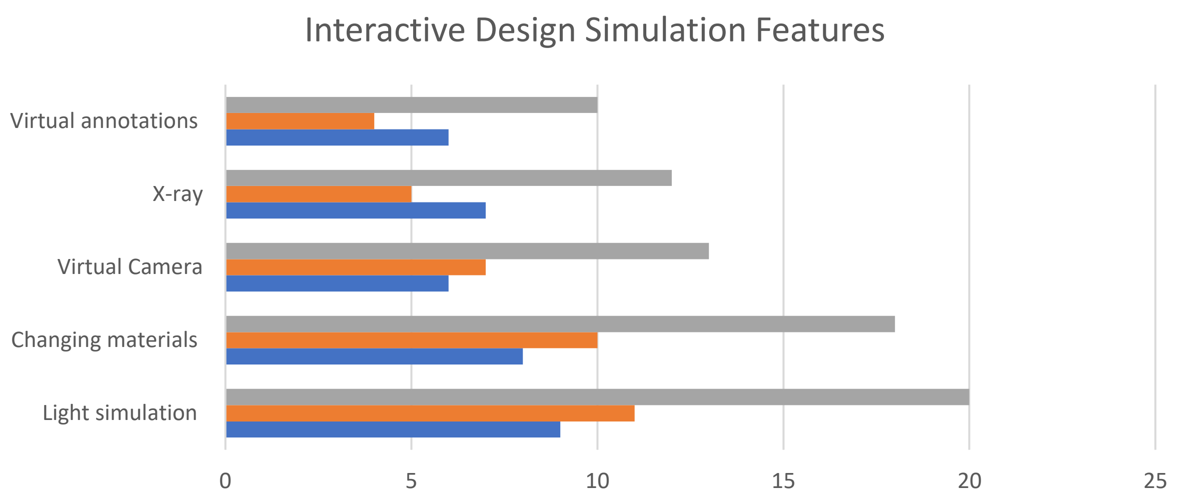
Throughout the experimental process, the interactive design process was bifurcated into two distinct sub-themes: **interactive design simulation** and **real-time design**.

Interactive design simulation bestowed participants with the capability to control and scrutinise diverse design scenarios within the space, encompassing aspects such as light simulation, which facilitated real-time evaluation of lighting conditions under varying times of day and seasons. Other facets included material modifications for design objects such as floors, walls, tables, and seating areas; X-ray functionality permitting participants to manipulate and obscure specific design objects; virtual annotations enabling the highlighting and sketching of preferred changes and requirements within the space; and the utilisation of a virtual camera for capturing rendered images and screenshots of real-time modifications and edits (Table 7.2).

The first experiment using the interactive gaming VR platform based on the Unreal Engine demonstrated positive outcomes for the participants. The platform allowed them to manipulate the spatial design of the Sky Garden model, testing and capturing various design scenarios (Figure 7.12). Key themes that emerged included altering the spatial organization of the space by moving objects and design fixtures to create more areas for social interaction, as well as spaces for relaxation and privacy. Participants also experimented with changing the materials of walls, floors, and restaurant spaces to make the Sky Garden more visually appealing and colourful. Furthermore, some participants, particularly designers, employed the VR annotation tool to emphasize their design concerns, offering ideas and suggestions such as incorporating more plants and water features.

The findings revealed that the participants found light simulation and material alterations to be the most efficacious simulation tools, considerably augmenting their interactive experience. Furthermore, the virtual camera was lauded for its enjoyability and utility, providing flexibility in capturing real-time spatial alterations and serving as an effective communication conduit between users and designers. Lastly, a majority of experts and designers underscored the importance of X-ray functionality and virtual annotations as invaluable interactive design tools, instrumental for testing various design strategies and facilitating communication among project team members (Figure 7.13).

Figure.7.12 Participants testing the interactive design features in real-time. Source: Author.



	Light simulation	Changing materials	Virtual Camera	X-ray	Virtual annotations
Total	20	18	13	12	10
Users	11	10	7	5	4
Designers	9	8	6	7	6

Figure.7.13 Graph chart for the participants selection of the interactive design simulation features. Source: Author.

7.3.1. Real-time Design: Leveraging Revit BIM Software and Enscape Plugin

Capitalising on the synergy of Revit Building Information Modelling (BIM) software and the Enscape plugin, the investigator of this study provided a real-time design experience within the Virtual Reality (VR) framework, a feature unattainable in the Unreal Engine. This capability was identified by a significant number of participants (n = 26) as a robust, captivating attribute that holds immense potential for clients and architects, particularly in the preliminary design stages, due to its potential for conserving time and effort.

This approach was put to test by the participants during the second experimental phase. As they traversed through the virtual environment of Crossrail Place, participants frequently voiced their design apprehensions and pinpointed elements they desired to be introduced into the space. A substantial proportion of participants (n = 21) asserted that the present design of Crossrail Place Roof Garden warranted enhanced interaction, proposing novel design scenarios and activities with the potential to attract a larger visitor base (Figure 7.14).

The most prevalent design themes proposed by participants, and subsequently tested in real-time through modifications enacted by the investigator using Revit, encompassed elements such as water features, spaces designated for exercise, public art installations, comfortable seating areas, an expanded selection of flora, open plazas designed to host events, gaming areas, outdoor cafés, and spaces catered to animals such as birds and butterflies (Table 7.2).

Such findings underscore the potential benefits of integrating BIM software with VR technologies in facilitating an immersive, interactive, and dynamic design process, fostering an enhanced level of user engagement in the architectural design process.

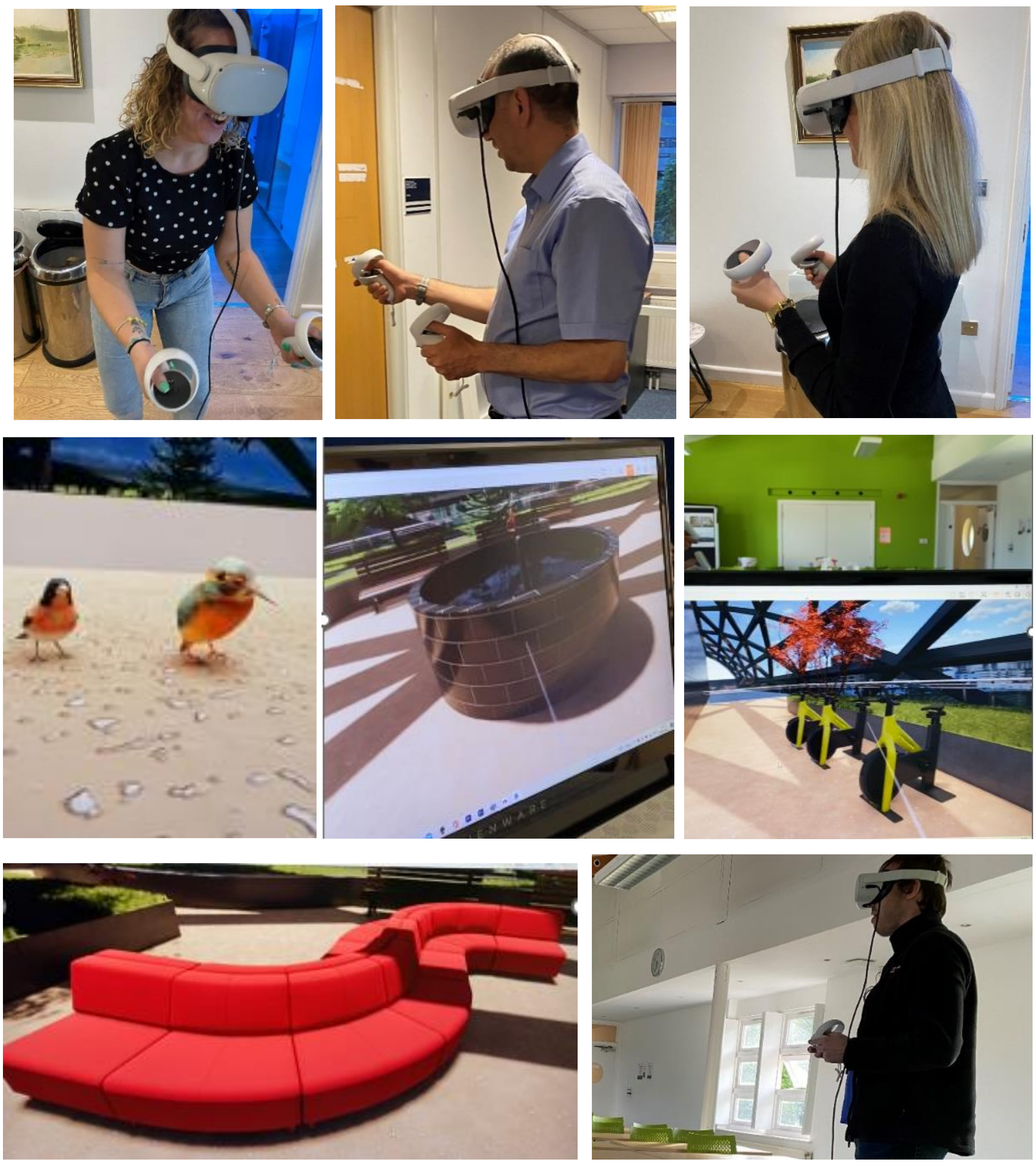
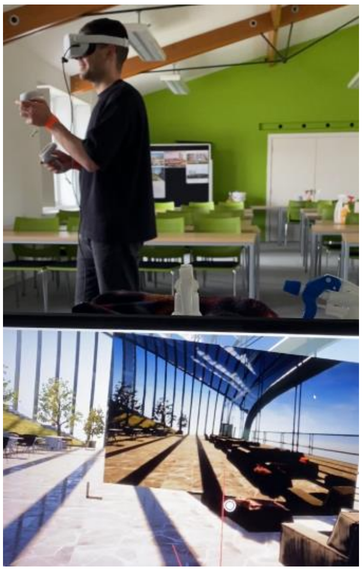
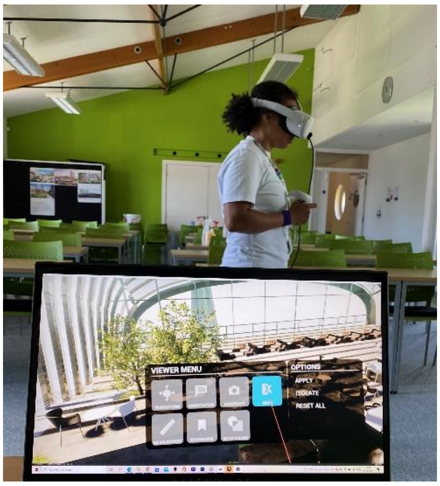
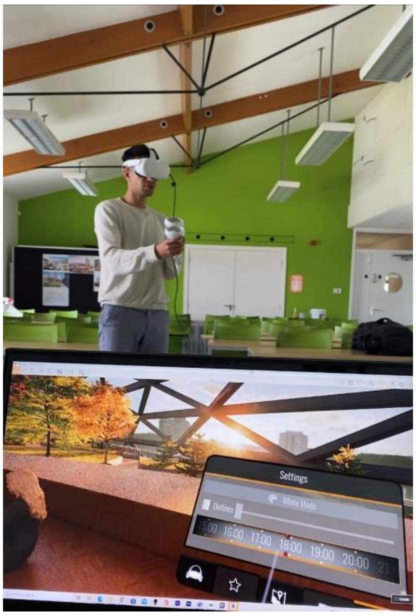
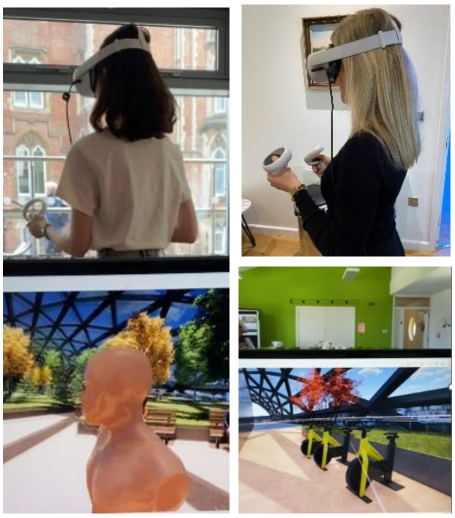


Figure.7.14 Participants testing their design ideas and suggested activities in real-time. Source: Author, video link: https://www.youtube.com/watch?v=F1maaDBdyAg.

Table 7.2: Displaying the differences between the main interactive design features tested by the participants on both VR platforms (Source: Author).

Design Feature	VR Platform	Participant Quotes	Image
Changing materials	Unreal Engine	*"I appreciated the ability to change materials and modify the design of elements. It's a potent interactive tool, particularly for visual learners."*	
Virtual camera	Unreal Engine and Enscape	*"I enjoyed using the virtual camera in VR; it was engaging and encouraged me to explore different design alternatives. Capturing these static images of the changes allowed me to compare them at my convenience."*	
X-ray and virtual annotations	Unreal Engine	*"The X-ray and annotation features are valuable for architects, enabling free line drawing and aiding in identifying design constraints. It's an excellent collaboration tool for design teams and clients during the design process."*	

Light simulation	Enscape	*"Undoubtedly, the light simulation was an exceedingly effective tool and well-executed. I believe it holds the potential to significantly influence design changes, making it more sustainable."*	
Real-time design	Enscape	*"I would like to see the roof garden as an adaptable space having different activities and themes that could be changed regularly."*	
		"I think a Calisthenics park, or an outdoor gym would be good for people to exercise in this open environment."	

7.3.2 Enhanced Design Exploration through VR and AI Integration

The encompassing scope of this research revealed a particular inclination among a subset of participants (n=8) towards advancing the exploration of potential design modifications to Crossrail Place, following their immersion in a VR experiment utilising Enscape software. Despite the immersive simulation offering an enhanced understanding of the site's architectural design and possible amendments, these participants harboured ambitions to probe and evaluate further design alternatives, which proved to be intricate to delineate. To overcome this complexity, they employed images rendered via the Enscape software from the VR experiment, integrated with the functionality of Versa, an AI plugin for Autodesk Revit. Through the use of descriptive directives, participants were able to lucidly illustrate their envisaged alterations to Crossrail Place, inclusive of the integration of mosaic and bamboo materials, the introduction of trailing plant species, and the erection of water fountains (Figure 7.15). This discovery underscores the advantageous potential of employing VR and AI technologies within the framework of architectural design, thereby facilitating a more precise and informed exploration of design potentials.

One participant, a landscape designer, posited that: *"My vision extends to the incorporation of a water feature within Crossrail Place, as it holds the potential to foster a dynamic ambiance. The tranquil sounds emitted could provide a soothing influence for those engrossed in reading, whilst concurrently serving as an engaging diversion for passing visitors".*

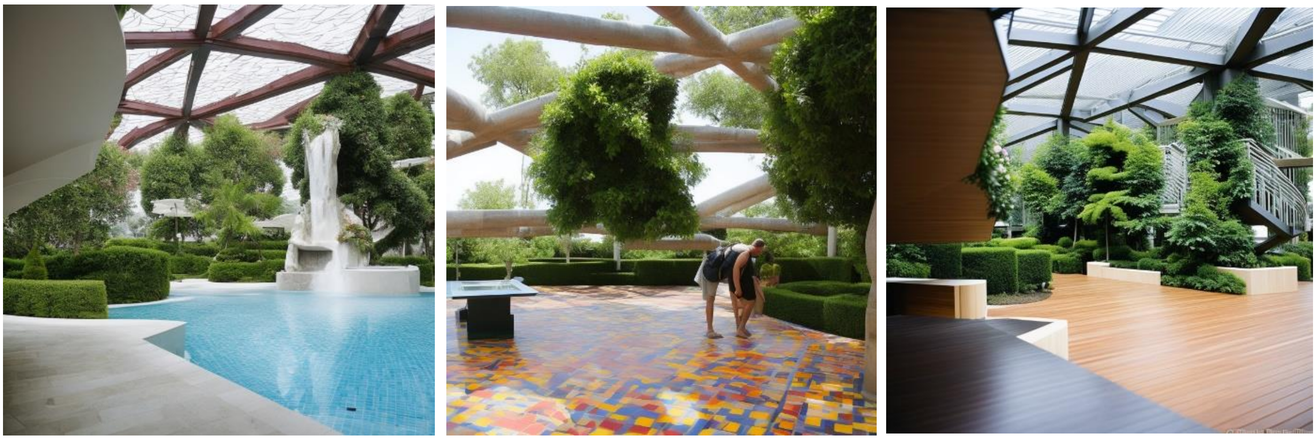


Figure.7.15 AI-generated designs for the Crossrail Place roof garden created by participants using VERAS on Revit. Source: Author

7.4 Chapter Summary

The chapter provides an in-depth analysis of a laboratory experiment employing VR to explore the potential of various tools in establishing interactive design models. Two distinct methodologies were examined: the Building Information Modelling (BIM) software "Autodesk Revit + Enscape", and the "Unreal Engine" game engine. This comparison aimed to determine the effectiveness of these tools in creating an enhanced design experience for social spaces and stimulating community engagement.

The research utilized VR and Visual Simulation (VS) technologies to create immersive environments of two urban green spaces in London, namely the Sky Garden and Crossrail Place. Participants were then guided through these spaces to capture their experiences and feedback. The methodology aimed to offer a comprehensive understanding of user experience, which was subsequently used to refine the design aspects of these social spaces.

Three major themes emerged from the subsequent analysis: virtual circulation, participant interaction, and interactive design. Each theme incorporated specific sub-themes. The 'virtual circulation' theme evaluated aspects such as spatial circulation design and the effectiveness of different teleportation methods employed by Unreal Engine and Enscape. It was observed that motion sickness, a common concern in VR experiences, could potentially be mitigated by limiting VR usage to a maximum of 20 minutes, coupled with regular breaks. Furthermore, a hybrid teleportation method seemed to enhance participant safety during navigation in the virtual environment.

The theme of 'participant interaction' focused on the participants' design-related concerns about both gardens. The participants identified various design limitations in both spaces, including the need for increased green areas, expanded public seating spaces, reorganization of seating areas to enhance privacy and social distancing, and improvements in accessibility. These findings underscored the utility of VR in involving end-users in the design process, allowing for more nuanced adjustments to design features based on user feedback.

The third theme, 'interactive design', explored the use of VR and BIM software in architectural design. This theme included an examination of the comparative effectiveness of the Unreal Engine and Enscape in creating interactive design simulations and real-time design experiences. Participants could manipulate and evaluate various design scenarios, with light simulation and material alterations proving to be the most effective simulation tools. The fusion of BIM software with VR technologies was observed to augment user engagement in the design process significantly.

Additionally, the research posited the potential of integrating Artificial Intelligence (AI) with VR to facilitate a more precise and informed exploration of design potentials. AI's capability of processing and interpreting large volumes of data in real-time could greatly enhance the VR experience by providing instant feedback and suggestions, thus further improving the design process. This potential of AI-VR amalgamation suggests an exciting future direction for architectural design methodologies.

Chapter 8 - Discussion and Conclusions

8.1 Introduction

This chapter comprises an exhaustive summarisation of the salient findings yielded from the data analysis, drawing upon results and theories from antecedent research pertinent to the topic under scrutiny. It engages in an insightful discussion on the correlation between the outcomes of the study and the research objectives outlined. This chapter renders a critical review of the research outcomes, highlights the primary contributions of this investigation, and proposes avenues for prospective research endeavours (Figure 8.1).

More specifically, the inaugural section puts forth a synopsis of research findings juxtaposed against previous research within this domain. This section unfolds in three distinct parts; initially, it outlines guidelines and a framework pertinent to the design of elevated social spaces, thereby emphasising the research's significance. Subsequently, the second part embarks on an exploration of findings that surfaced from the virtual study and executes a comparative study between the disparate Virtual Reality (VR) systems utilised within the study. The third part engages in a discourse on the cross-reference between both the physical cognitive study and the virtual study, thereby illuminating their similarities and disparities. It further elucidates the efficacy of VR as a co-design participatory design method for elevated social spaces.

The ensuing sections, being the fifth and sixth sections of this chapter, delve into the implications of these findings and their contribution to both knowledge and the practical sphere of urban and architectural industry. The chapter subsequently delineates the limitations that encumbered the study, thereby introducing a degree of circumspection in the interpretation of the findings. Lastly, the chapter concludes with a set of cogent recommendations for future research, thereby paving the way for further exploration and validation of these findings in the future.

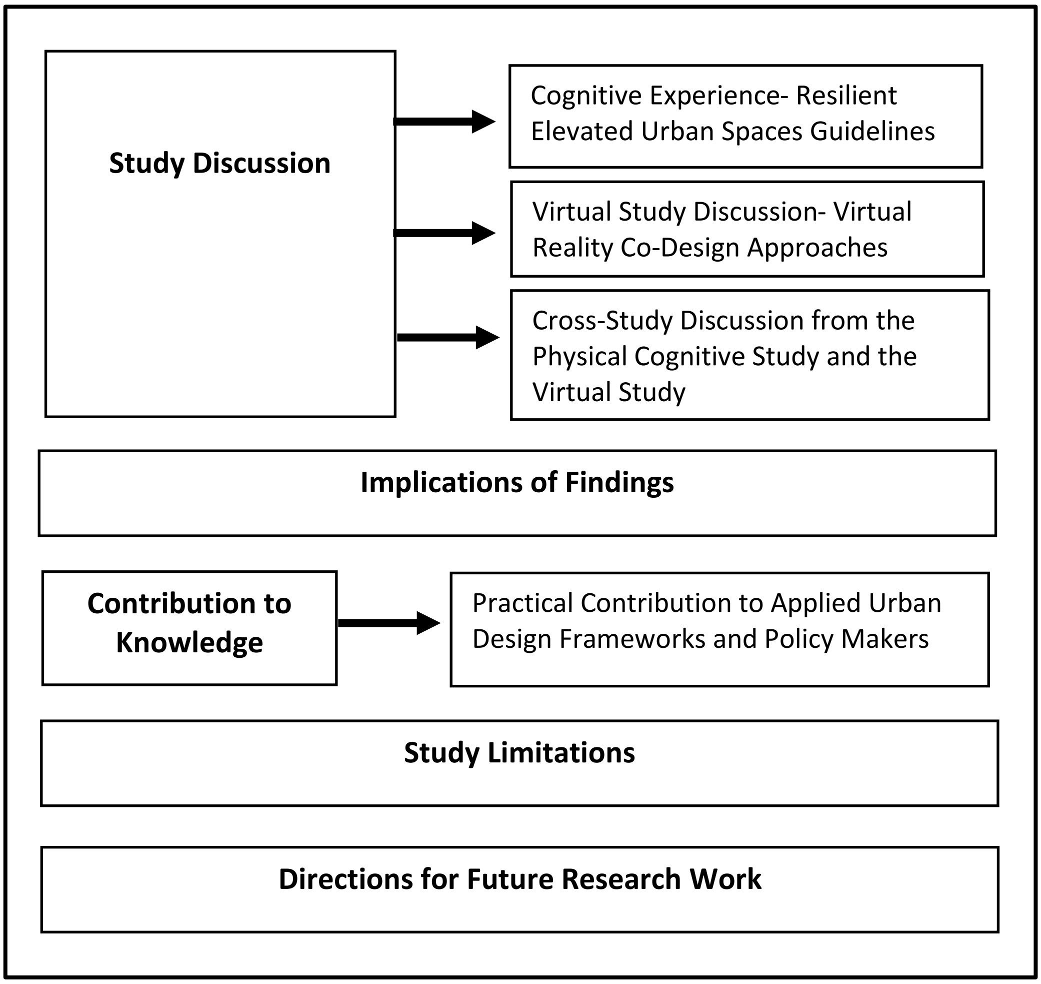


Figure 8.1: Flowchart illustrating the primary sections covered in Chapter 8. Source: Author.

8.2 Cognitive Experience Design Guidelines Principles and Framework

The present research scrutinizes the multifaceted design challenges and guiding principles inherent to the planning of resilient elevated urban spaces. The dual case studies highlighted reveal numerous areas of potential enhancement, encompassing accessibility, circulation, aesthetic appeal, and management strategies. The results of this study align with previous studies which discussed the design problems and principles that need to be considered when designing vertical urban spaces (Oldfield, 2019; Cho et al., 2015; Pomeroy, 2013). The investigation uncovered seven salient attributes consistently identified by participants as critical components of their conceptualized ideal elevated urban environment or rooftop garden (Figure 8.2). These essential characteristics include accessibility, efficient circulation, opportunities for social interaction and activity, a sense of security and safety, defined publicness and territorial rights, competent management, and a participatory co-design approach.

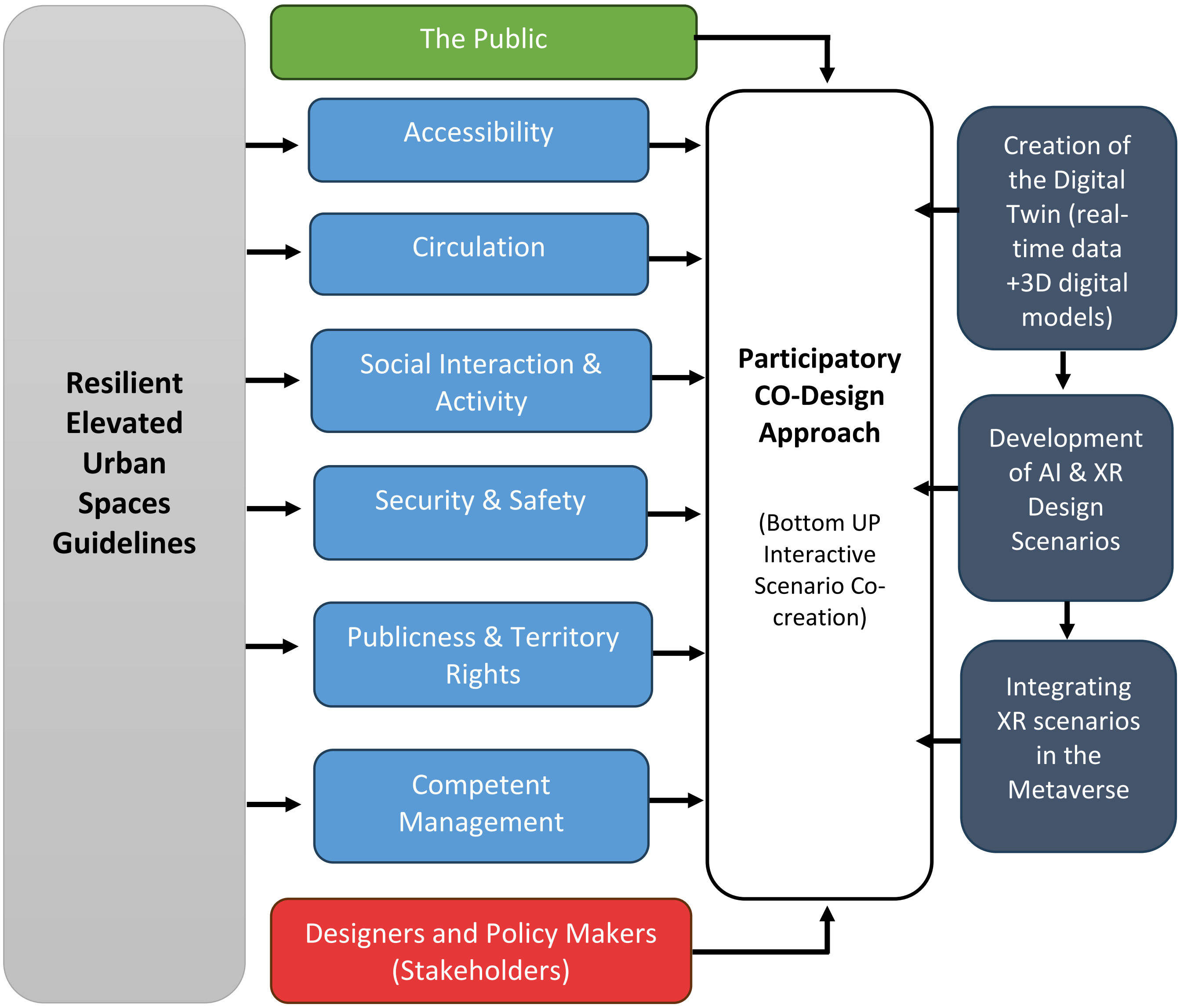


Figure 8.2: Resilient Elevated Urban Spaces Guidelines Principles and Framework. Source: Author.

8.2.1 Accessibility

The resilience of urban spaces, from a functionality perspective, is largely contingent upon the pedestrian accessibility (Carmona et al., 2008; Whyte, 1980). This study, substantiated by the observational evidence and participant interviews, affirms this assertion. Accessibility encompasses the universal reachability of a space, unhampered by any pre-existing or anticipated constraints (Persson et al., 2015). A nuanced approach to pedestrian access has the potential to foster logical motion patterns and promote desired behaviours, consequently ameliorating the inclusivity quotient (Pineo, 2022; Aelbrecht & Stevens, 2019).

Carr et al. (1992) conceptualised three physical access forms: visual, physical, and symbolic. Visual access grants the prospective users a preview of the space, physical access regulates user entry, while symbolic access infers safety and hospitality through spatial indicators (Mehta, 2014; Németh, 2009).

Application of these principles to the case studies of Sky Garden and Crossrail Place highlights unique intricacies related to accessibility (Figure 8.3). The Sky Garden, while offering public facilities and visitor areas that are ostensibly freely accessible, confronts substantial obstacles in terms of physical and visual accessibility. These limitations ultimately shape the perceived publicness of the space. A significant contributor to this issue is the prerequisite for visitors to pre-book a time slot a minimum of two weeks in advance, which creates a barrier to spontaneous or unplanned visits. Additionally, the garden's position at the apex of the towering 'Walkie Talkie' building inherently curtails visual accessibility from the street level, thereby impeding the perception of openness and publicness.

The Covid-19 pandemic further intensified these accessibility challenges. Safety protocols mandating physical distancing led to a shrinkage in the allowable visitor count and elevator capacity. Additionally, the pressing need for natural ventilation - a direct response to the pandemic - presented additional difficulties due to the garden's high-rise location and dependence on artificial environmental control systems. This crisis underscored the vulnerability of such elevated spaces to unexpected global events and emphasised the importance of adaptable and resilient design approaches.

Contrastingly, at Crossrail Place, the primary accessibility issue stemmed from the poor visibility of the roof garden from ground level. This issue was particularly pronounced among first-time visitors who found navigating to the garden without directional signs or digital maps perplexing. Even though the garden was accessible via an escalator, the overall layout of the venue was deemed confusing, and the visibility was reported as inadequate. While public transportation options, including the Elizabeth Line, the Jubilee Line, and local bus services, augmented accessibility, the special-needs accessibility received a mixed response. While the garden was deemed wheelchair-accessible, the lift's positioning and obstructed view were criticized.

To enhance the appeal and functional utility of such elevated spaces, a multi-modal transportation approach, a direct connective pathway from the street-level to the roof garden, and effective symbolic indications (like visible green foliage from the street level as an invitation) are recommended (Viñoly et al.,2015; Yeang, 2002; Samant, 2019). Moreover, special needs accessibility needs to be explicitly factored into the design to ensure universal access. Simply put, for these spaces to serve their intended purpose, visitors must find them readily accessible and feel at ease manoeuvring within them.

Ultimately, the inclusive accessibility of elevated urban spaces is not a mere design nicety; rather, it forms a critical cornerstone of their usability and success. Providing comprehensive, user-friendly access to these spaces is paramount in fostering their public utility and social significance. It allows for a diverse range of users to engage with the space, engendering a sense of community and collective ownership. Furthermore, it aids in promoting social interaction and contributing to the overall vibrancy of the urban landscape.

This investigation has highlighted the unique challenges and opportunities posed by the two case studies, demonstrating the necessity for careful, thoughtful planning and design. Each location possesses its distinctive contextual parameters that require targeted strategies. Consequently, there is no 'one-size-fits-all' solution; rather, solutions must be carefully adapted to their respective urban contexts.

Moreover, these findings underscore the dynamic and evolving nature of accessibility, shaped by societal changes and events such as the Covid-19 pandemic. It is essential that urban planners and designers remain responsive to such shifts, ensuring that these spaces remain accessible and inviting, even in the face of unforeseen challenges. Thus, future research should continue to explore this multifaceted issue, with a focus on novel strategies for enhancing accessibility in a rapidly changing urban landscape.

Accessibility

- **Visual Access**: This factor emphasizes the importance of the visibility of the space from ground level and from various street vantage points. It influences the perception of openness and publicness of the space. Limited visual access from street level can affect spontaneous visits and engagement with the space.
- **Physical Access (Mobility):** This reflects how easily individuals can reach and navigate within the space. A successful design emulates a journey, activating the use of ramps, escalators, and stairs as a vertical street moving between different levels. Physical barriers, such as the requirement for pre-booking and security entrances, can limit mobility and should be minimized.
- **Connection to Public & Active Transportation**: This factor looks at how well the space is linked with public and active transportation systems such as bus stops, trams, underground trains, and cycling paths. This connectivity can greatly enhance the overall accessibility of the space.
- **Economic Accessibility:** This pertains to the potential financial barriers to using the space. This includes the cost of goods or services within it, entrance fees, and any other potential expenses that might discourage or prevent entry and usage.
- **Inclusive Design:** Universal design principles should be incorporated to ensure the space is usable by as wide a range of people as possible. Special attention must be paid to ensure the space is friendly to those with special needs, considering elements like the position and visibility of elevators or lifts, and wheelchair-accessible routes.
- **Signage and Directions:** Clear and sufficient directional signs are necessary for first-time visitors and overall user experience. Navigational challenges can deter people from accessing the space and can affect the overall perceived accessibility of the space.

Figure 8.3: Conceptual Framework Illustrating the Principal Aspects of Accessibility for Resilient Elevated Social Spaces. Source: Author.

8.2.2 Circulation

Both the Crossrail Place and Sky Garden case studies offer substantial data regarding the circulation within their respective spaces. The analyses yield both congruent and divergent results, and when combined, these findings make meaningful contributions to the literature on elevated social spaces' design principles.

In the case of Crossrail Place, the primary focus lies on the impact of the garden's curved pathways on visitor experiences. The curved paths encouraged exploration, a concept that fits well with Kaplan's (1995) notion of 'mystery' in preference studies, where people show an affinity towards environments that seem promising but don't entirely reveal what is there (Kaplan,1995; Taylor & Lovell, 2021). Participants praised the garden-like feel and natural layout of the garden's circulation system. These comments align with the principles of landscape architecture, which value natural elements, shade, and attractive features in public spaces and elevated social spaces (Rivera et al., 2021; Veitch et al., 2020; Cho et al., 2015). However, participants identified the narrowness of the pathways as a potential issue for larger groups and for those desiring a sense of privacy when seated, indicating a need for broader walkways and additional private spaces in elevated gardens.

In contrast, the Sky Garden study underlined the significant impact of the Covid-19 pandemic on the circulation within the space. To ensure public safety, the garden's management implemented a one-way circulation system, with clear markings for social distancing (Cheshmehzangi, 2020; Pinheiro & Luís, 2020). This system, while deemed necessary by many, limited the freedom of movement, contrasting sharply with Whyte's (1980) principles of open access and unrestricted movement in public spaces.

The pandemic has forced the managers of elevated urban spaces to rethink sightlines and wayfinding to provide good visibility in terms of horizontal and vertical directions. To ensure safety, these strategies should emphasise visibility from both inside and outside the points of the entrance and exit. A larger and more visible area allows for increased safety measures such as social distancing to be upheld while allowing pedestrians greater freedom of movement (Honey-Rosés, 2020; Cho et al., 2015). An environment with a heightened sense of connectivity will not only reduce the risk of exposure, but also promote accessible routes within public spaces (Afrin et al., 2021; Pineo, 2022).

A well-connected space is integrated with local movement and pattern systems; the movement is itself an activity that often generated other activities (Moore, 2021; Carmona et al., 2010). Legible spaces are essential for the identification of prominent activity nodes. To be effective, elevated roof gardens should provide a balanced mix and visibility to all activities; it should encourage users to engage with the environment and also have moments to pause (Pomeroy, 2013; Cho et al., 2015).

The pandemic further amplified the usage of outdoor spaces for stationary activities, an observation aligning with Oldenburg's (1999) 'third place' theory, which posits that public spaces should encourage casual gatherings and social interactions. Meanwhile, the introduction of new amenities, such as chaise lounges, fostered leisure and relaxation, revealing the capacity for public spaces to evolve and meet emerging needs, in line with Gehl's (2011, 2013) emphasis on flexibility in public space design.

However, the one-way system also drew criticism from some participants, as it restricted spontaneous revisits to particular vistas. This limitation highlighted Lynch's (1964) urban design principles, which emphasize the importance of allowing people to navigate spaces freely. Nonetheless, other participants appreciated the focus this system brought to their exploration, underlining the subjective nature of public space experiences.

The multi-level design of the Sky Garden is generally appreciated for introducing dynamism into the exploration of the space, enhancing visitors' experiences with shifting perspectives. However, it's important to consider that while this structure enriches the spatial experience for many, it might impose accessibility challenges for individuals with mobility impairments, underlining the importance of universal design principles in public spaces (Imrie, 2012; Iwarsson & Ståhl, 2003). Such principles advocate for equitable access, flexible use, and intuitive design (Welage & Liu, 2011; Carlsson et al., 2022). The case of the Sky Garden underscores the need to balance engaging spatial features with accessibility, ensuring that design innovations are implemented thoughtfully to prevent exclusion and guarantee comfortable navigation for all visitors. This integration of dynamic design and universal accessibility is a crucial aspect of creating elevated social spaces.

In conclusion, the findings of both case studies offer valuable insights into the multifaceted nature of circulation in elevated social spaces (Figure 8.4). The varying participant experiences highlight the need for designers to strike a balance between facilitating exploration and maintaining accessibility, privacy, and safety in their designs. These case studies reinforce and extend the principles laid out by urban theorists such as Kaplan, Whyte, Oldenburg, Gehl, and Lynch, offering novel perspectives in the context of elevated gardens in a pandemic-stricken world.

Circulation

Exploratory Paths and Dynamic Experiences: Incorporate design elements like curved pathways and multi-level structures to foster a sense of exploration and offer shifting perspectives, enhancing visitor experiences.

Spatial Capacity and Connectivity: Pathways and spaces should align with local movement patterns and accommodate diverse group sizes. Well-defined sightlines and spatial capacities enhance safety, intuitive navigation, and a sense of openness.

Pandemic Response and Adaptability: Design should be flexible and adaptive, incorporating safety measures like one-way systems and social distancing markers during pandemics, while also being able to evolve to meet emerging societal needs.

Balanced User Experience in Circulation: The circulation design should facilitate a mix of activities and promote a dynamic flow of users. It should enable users to engage with the environment, offering varied routes that cater to active movement, spontaneous exploration, and pauses for rest or observation. This balance enhances the overall circulation and fosters a rich, multi-faceted user experience within the space.

Inclusive and Accessible Design: Circulation design should follow universal design principles, ensuring the space is accessible for all, including those with mobility impairments, and offers a balance between structured and spontaneous navigation.

Figure 8.4: Conceptual Flow Chart Illustrating the Principal Aspects of Circulation for Resilient Elevated Social Spaces. Source: Author.

8.2.3 Social Interaction and Activity

The results from both case studies, the Sky Garden and Crossrail Place, provide a multifaceted view of how elevated social spaces can be used and navigated. These spaces are evidently highly valued by the public for various activities including walking, viewing, socializing, and relaxation, as observed in both pre- and post-pandemic periods.

At the Sky Garden, the capacity to hold 600 visitors underscores its potential for significant social interaction. The average occupancy during weekends and weekdays suggests that a significant number of individuals utilize the space regularly, with walking being the primary activity, according to the observations. The fact that this activity was dominant in both venues supports previous studies suggesting that providing opportunities for walking is a critical aspect of public space design. The study also recognized six distinct optional and social activities, with stationary activities being the second most popular, reflecting prior research underlining the need for spaces that accommodate static activities like sitting, eating, and reading.

During the pandemic, a noticeable shift was observed with a significant reduction in visitor numbers at the Sky Garden. However, the relaxation of COVID regulations led to an increase in the usage of the roof garden stationary activities such as eating, drinking, and chatting became prevalent, which aligns with research suggesting that spaces encouraging relaxation and stationary activities foster more social interaction (Carmona, 2010; Gehl, 1987). Moreover, special events held at the Sky Garden attracted diverse audiences, emphasizing the importance of programmability in public spaces (Smith, 2015; Francis et al., 2012). Yet, concerns about high costs associated with the venue's food and beverages were raised, underlining that economic accessibility is an essential factor for the regular use of public space.

This study has identified an increase in both the number of people visiting Crossrail Place during the pandemic and the average time visitors spent there. This increase in the number of youths, children, and families visiting the roof garden reveals the sense of safety and security in the place. Overall, the majority of the participants (90%) found the roof garden to be a safe place to visit during the COVID-19 pandemic due to the roof ventilation and the high-security. The study also highlighted the presence of new activities taking place in the roof garden during the pandemic such as reading (short story stations), relaxing, playing, and family picnics. A significant percentage of the participants (41%) reported that visiting the roof garden on regular basis during the pandemic to sit, relax, and chat with friends had a positive impact on their mental well-being. The introduction of installations inspired by the Jardin Majorelle in Marrakesh resulted in increased visitor numbers and new activities, suggesting that temporary events and features can enhance public engagement. Yet, maintenance issues due to heavy usage were noted, highlighting the importance of maintenance in public spaces.

Seating organization is one method to facilitate social activity in vertical green spaces and a variety of seating types is therefore advisable. The main challenge with seating fixtures in roof gardens is not the lack of provision, but instead, the arrangement and positioning of seating, grouping, design, the level of flexibility, and availability of weather protection. Key aspects of quality seating in roof gardens therefore include flexibility and adjustability, together with comfort, and arrangement (Cho et al., 2015; Nordh & Østby, 2013). Indeed, movable chairs and benches with different orientations can improve the variety and choice of seating, for comfort and user experience. When implemented well, good seating improves social interaction and passive activities, such as people watching others. Interactive objects of interest such as fountains, plants, installations, game facilities, interactive displays, pianos, swings, and public art sculptures are also highly recommended to activate a public roof garden. These elements bring a unique character to the roof garden while also serving as an attraction that encourages visitors to stay longer, or return later with friends (Rivera et al, 2021).

The overall findings indicate a balance is needed between dynamic and static activities and that designing elevated social spaces should be flexible to accommodate various user needs and preferences (Figure 8.5). Such findings align with the universal design principles emphasizing equitable use, flexibility in use, and size and space for approach and use. Despite each case study's unique context, they both serve to extend our understanding of how elevated social spaces can foster social interaction and engagement, providing valuable insights for future design and research.

Social Interaction & Activities

Dynamic and Static Activities: Elevated social spaces should facilitate both dynamic (e.g., walking) and static (e.g., sitting, eating, reading) activities. This balance ensures the space accommodates diverse user needs and preferences, fostering broad engagement

Flexible Seating Arrangements: Quality seating in these spaces is not just about provision but includes flexibility, adjustability, comfort, and thoughtful arrangement. Different seating types, orientations, and the option for mobility can enhance user experience and social interaction.

Interactive Features and Installations: The presence of interactive objects of interest, such as fountains, plants, installations, game facilities, interactive displays, and public art sculptures, can add character to the space, serve as attractions, and encourage longer stays or repeat visits.

Programming and Events: The organization of special events can attract diverse audiences, thereby enhancing the vibrancy and utilization of the elevated social spaces.

Infrastructure Sustenance and Stewardship: In the context of elevated social spaces that often see heavy usage, the maintenance and management of infrastructure become imperative. An effective stewardship strategy ensures the persistent allure and functional integrity of the space, thereby prolonging its usability and relevance to its users.

Figure 8.5: Conceptual Framework Illustrating the Principal Aspects of Social Interactions & Activities for Resilient Elevated Social Spaces. Source: Author.

8.2.4 Security and Safety

The findings from the two case studies offer crucial insights into the role of security and safety in elevated social spaces.

At the Sky Garden, a notable security presence was perceived as a deterrent to illicit activities, increasing the sense of safety for the majority of participants. This aligns with previous studies that have highlighted the role of visible security personnel in enhancing users' sense of safety in public spaces (Mehta, 2014; Fisher & Nasar, 1992). However, around a quarter of the participants felt discomfort from the constant surveillance, reflecting existing research that has highlighted the potential negative psychological impact of excessive security measures, leading to feelings of intrusion (Koskela, 2002; Lofland, 2017). Therefore, designers of elevated social spaces need to strike a balance between ensuring security and maintaining the comfort and privacy of the users.

Moreover, the process of online booking emerged as a barrier to frequent visitation, implying that designing access to elevated social spaces should not only consider physical accessibility but also procedural ease and convenience. This finding aligns with previous research that has emphasized the importance of easy access in determining the usage of public spaces (Gehl & Svarre, 2013; Whyte, 1980).

During the pandemic, the Sky Garden management team effectively addressed the issue of social distancing by implementing a one-way system and ground markings to regulate movement within the venue. This intervention aligns with design recommendations that emerged during the pandemic, which stress the importance of adaptable design measures to cope with social distancing requirements.

The Crossrail Place roof garden was perceived as a safer option during the pandemic due to its open and well-ventilated nature, reflecting the growing demand for such spaces in urban environments. The participants' sentiments correlate with previous research highlighting the psychological benefits of natural spaces in urban environments, especially during periods of stress and crisis (Vujcic et al., 2017; Jackson et al., 2021; Kaplan, 1995; Kaplan & Kaplan, 1989).

The participants' comments on the future of roof gardens underline the need for more open and ventilated spaces, especially considering the ongoing loss of ground-level green spaces. This reflects the broader global trend towards vertical greening as a sustainable solution for cities, which integrates nature into urban fabric and offers numerous environmental and social benefits (Morakinyo et al., 2019; Magliocco, 2018).

The building industry needs new strategies to manage risk and hygiene to combat the transformation of Covid-19 and future diseases, but also new thinking on how to create resilient and vertical social spaces that allow for high-value interaction and increased health and wellness (Morawska et al., 2021). A number of possible solutions include a combination of operational, technological, and architectural inventions (Mills et al., 2020). These innovative solutions are firmly rooted in science and built upon the hierarchy of controls, a widely recognised industry standard for risk management. Safety organisations such as OSHA (U.S Occupational Safety and Health Administration) and HSE (UK Health and Safety Executive) advocate this solution to manage risks effectively (Shroff, 2020). To reduce the probability of risks in any built environment, this hierarchical system categorises design solutions or operational measures according to their effectiveness.

The inverted pyramid graphic creates a hierarchy of solutions, with those at the top considered to be more effective than the one at the bottom (Sehgal & Milton,2021; Morawska et al., 2020) (Figure 8.6). The use of personal protective equipment (PPE) was the initial response to the pandemic and will continue to serve an important purpose in the short to medium-term but these are considered less effective over the long-term (Gandhi & Marr, 2021). Design and engineering solutions at the top of the pyramid are, however, more suitable long-term solutions and are considered to be more effective (Mills et al., 2020).

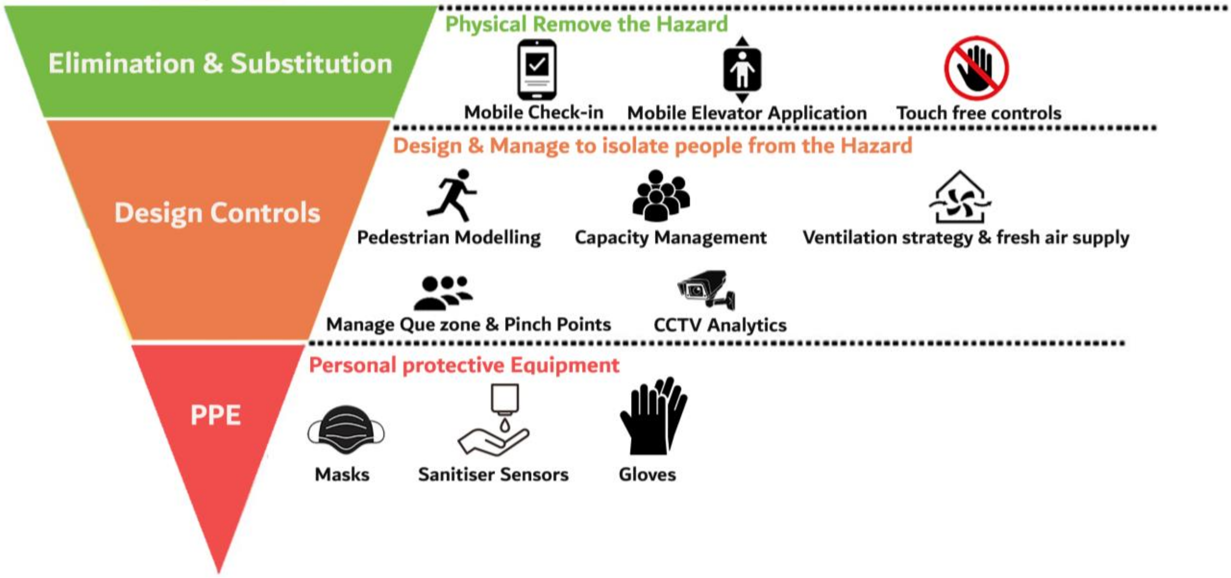


Figure.8.6. The Hierarchy of controls is a commonly accepted system for reducing risk. The icons to the right represent some of the specific solutions that can be implemented in the vertical social space to effectuate each control action., Source: Author.

Overall, these findings suggest that safety and security considerations should be integrated into the design of elevated social spaces to ensure that they are inclusive, accessible, and adaptable to changing circumstances. Importantly, they should also contribute to the mental wellbeing of users, which requires incorporating natural elements and providing opportunities for solitude and escape from city life.

8.2.5 Publicness and Territory Rights

From the two case studies, it becomes apparent that perceptions of publicness and territorial rights in elevated social spaces are multifaceted and complex.

In the Sky Garden case study, most participants identified the space as a 'private-public' area, with some categorizing it predominantly as private. Factors influencing these perceptions include mandatory pre-booking, security protocols, usage regulations, and the association of seating spaces with commercial entities. These findings resonate with existing literature on public space, which suggests that management practices and spatial organization within a location significantly impact the perceived publicness.

The case study of the Crossrail Place Roof Garden provides additional insights into the nuanced perceptions of publicness and territorial rights within elevated social spaces. Although participants identified the roof garden as safer than conventional public parks, there appeared to be a compromise between safety and freedom. They felt that the garden limited certain activities typically associated with public parks, reflecting existing research on privately-owned public spaces that often regulate or restrict certain behaviours. Additionally, some participants were not aware of the garden's rules and restrictions, indicating a potential area for improvement in communicating these regulations.

Responses from both case studies suggest that the design and management of elevated social spaces should balance safety and order requirements with the users' desire for freedom and a sense of publicness (Figure 8.7). These insights are congruent with established design principles advocating for flexible design that allows for a variety of activities and social interactions, as well as the importance of maintaining 'eyes on the street' to ensure safe and vibrant public spaces.

Future design interventions aiming to enhance the publicness of elevated social spaces might focus on improving transparency regarding rules and restrictions, fostering inclusiveness and a sense of ownership, and facilitating a variety of social activities. Moreover, thoughtful management strategies could help mitigate the perceived privateness of these spaces. For example, relaxing pre-booking requirements or reducing the correlation of seating spaces with commercial establishments could be considered. Subsequent research might further investigate these strategies and their impacts on user perceptions and experiences in elevated social spaces.

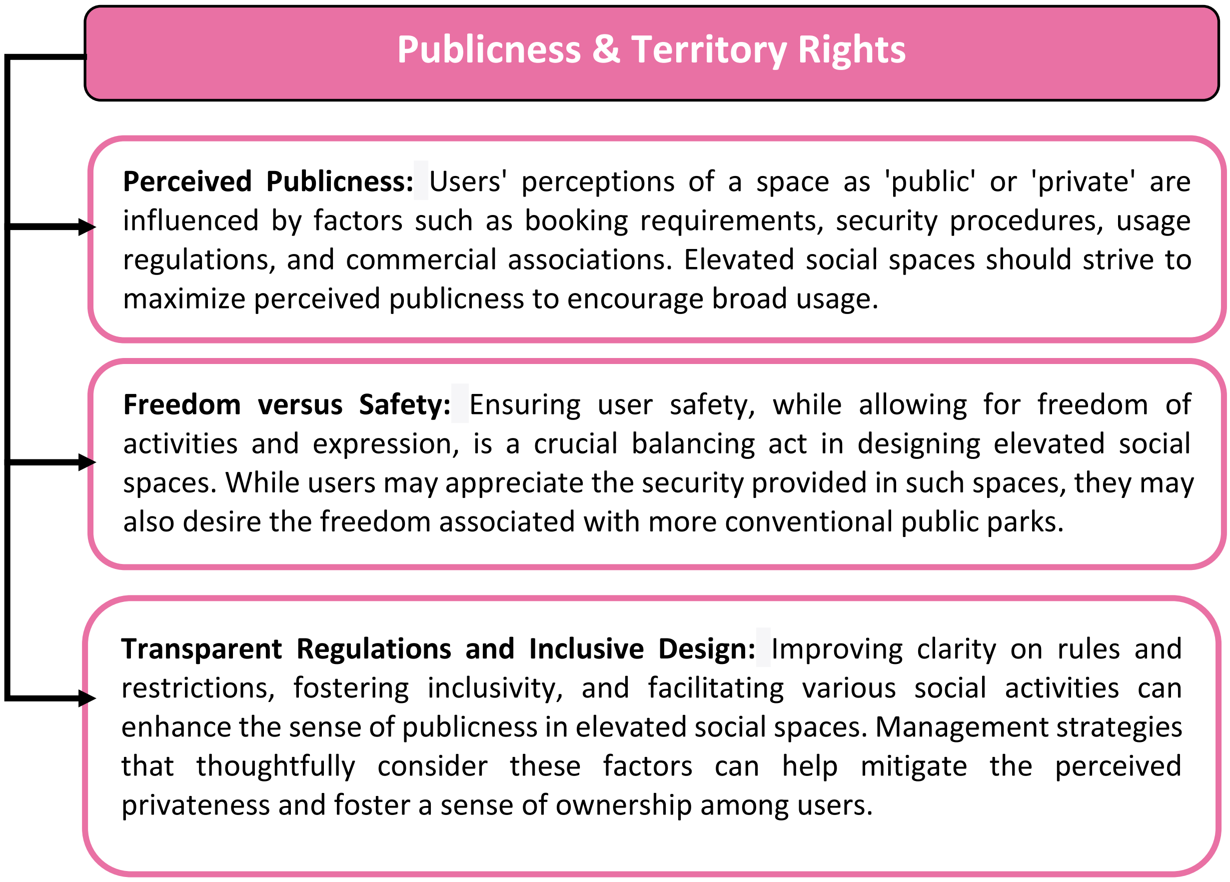


Figure 8.7: Conceptual Framework Illustrating the Principal Aspects of Publicness and Territory Rights for Resilient Elevated Social Spaces. Source: Author.

8.2.6 Competent Management

The astute administration of elevated social spaces necessitates an ethos of inclusivity. This inclusion is best fostered through flexible, light-touch regulations rather than rigid prohibitions that might exclude individuals or discourage certain behaviours (Hadi et al., 2018; Samant & Hsi-En, 2017; Oldfield, 2019). Rather than entirely barring people, activities, or animals based on perceived undesirable characteristics, management should adopt a nuanced approach, focusing on risk assessments that genuinely acknowledge potential nuisances and threats.

Indeed, there is an imperative for innovative, forward-thinking strategies that enhance vibrancy in these vertical public realms as opposed to inhibiting their potential. Therefore, new operational guidelines should aim to limit constraints, confining them to those that are essential and justifiable. Encouraging user participation in the stewardship of these elevated spaces, rather than merely governing their actions, can foster a sense of communal ownership and engagement. This involves adopting a regulatory approach that embraces the diversity of spatial uses and actions, as opposed to imposing prohibitions. For instance, designated safe areas could be integrated into the design for animals, individuals who smoke, and activities like ball games and skateboarding, thereby promoting a balanced, harmonious coexistence.

The analyses underscore the necessity for a cooperative management model in the oversight of these elevated social spaces. Rather than relying solely on investors' or stakeholders' rules and authority, a hybrid partnership should be formed between local councils or London boroughs and these stakeholders. This approach acknowledges that these spaces often serve as city landmarks, and their benefits, as well as their responsibilities, should not fall under a single entity's purview. The impact of these spaces extends beyond their physical boundaries, contributing significantly to the city's environmental strategy, the neighbourhood's ambiance, and residents' physical and mental wellbeing.

Hence, it is suggested that the governance of these spaces aligns with the principles enshrined in the London Public Space Charter. Such alignment ensures that the management respects the rights and expectations of all users, provides equitable access, and encourages a broad range of social activities, contributing to the vitality and vibrancy of these spaces. By adhering to these principles, elevated social spaces can truly serve their intended purpose as inclusive, engaging, and dynamic areas that enrich urban life.

In summary, a comprehensive approach to managing elevated social spaces involves balancing inclusivity with necessary regulation, fostering community participation, and establishing cooperative governance models (Figure 8.8). This multifaceted approach ensures that these spaces not only contribute to the physical environment but also play a crucial role in supporting the social, economic, and psychological wellbeing of urban dwellers. Future research should continue to explore and refine these management strategies, keeping in step with the evolving needs and aspirations of urban societies.

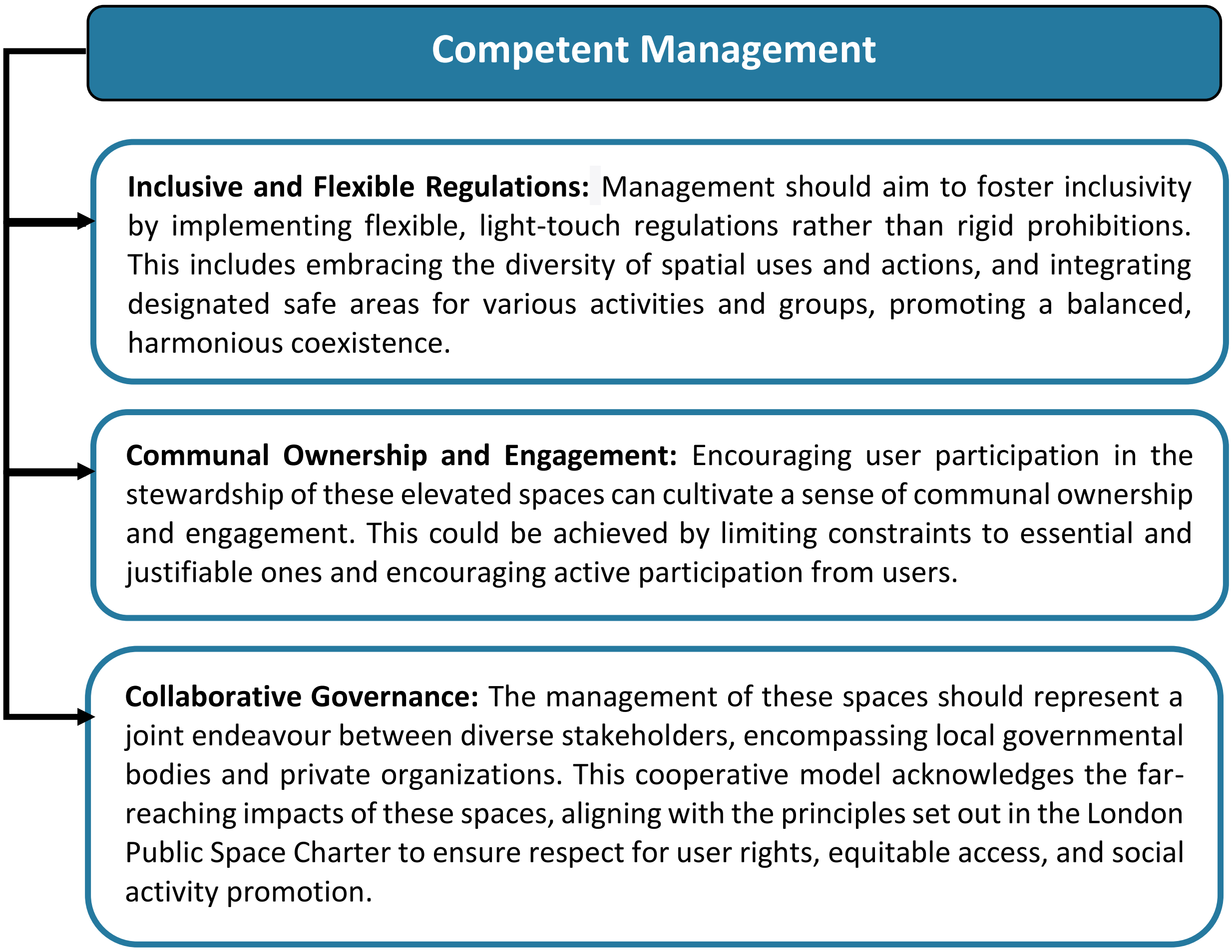


Figure 8.8: Conceptual Framework Illustrating the Principal Aspects of Competent Management for Resilient Elevated Social Spaces. Source: Author.

8.2.7 Participatory Co-design Approach

An appreciation of both physical and societal intricacies inherent to elevated social spaces is an essential foundation for their design. Drawing from the case studies of the Sky Garden and Crossrail Place, one may discern the substantial benefits of adopting a participatory co-design approach in the development of such areas. This method mandates the active engagement and cooperation of a wide array of stakeholders, encompassing designers, developers, city councils, local communities, and the public. It advocates the weaving together of a diversity of voices and perspectives, thereby facilitating the creation of spaces that are inclusive, accessible, and stimulating.

In the case of the Sky Garden, participants' feedback proved invaluable in identifying the merits of the site's design whilst pinpointing areas ripe for enhancement. For instance, whilst a common appreciation for the infusion of natural elements was evident, a pronounced call for improvements in aspects such as seating arrangements, plant variety, accessibility, and the overall site layout was also apparent. Moreover, recommendations for the introduction of additional design features and activities underscored the necessity for areas promoting social interaction and physical activity, as well as tranquil, serene spaces for individual pursuits. The solicitation of this feedback would not have been feasible without the application of a participatory co-design approach, thereby underscoring its importance in the crafting of spaces that genuinely resonate with the needs and desires of users.

The Crossrail Place case study likewise demonstrates that the employment of a participatory co-design approach can yield substantive insights into the practical and aesthetic facets of elevated social space design. Feedback from participants concerning the lack of shaded areas, constrictive pathways, and discomforting seating benches offered crucial areas for improvement. Concurrently, suggestions such as the incorporation of a water feature, enhancement of plant diversity, and inauguration of new activities, provide a direction for prospective improvements. Importantly, several participants expressed contentment with the existing design and voiced concerns over the potential for overcrowding or excessive noise, thereby underscoring the necessity to judiciously balance new feature introductions with the preservation of peaceful areas.

Through the lens of these case studies, the value of adopting a participatory co-design approach in the planning and development of elevated social spaces is starkly illuminated. Such an approach encourages diverse stakeholder involvement and ensures their perspectives and needs are considered in the decision-making process. This participatory methodology, therefore, not only fosters the creation of more inclusive and accessible spaces but also imbues a sense of ownership among users, thereby amplifying the overall sense of community and place attachment.

It is also opportune for designers to consider the potential of new technologies to better engage the public in the design process. Indeed, previous research suggests that the principles of intelligent design for these vertical social spaces should be used with the flexibility derived from a deeper understanding of justifications and interrelations. Computer modelling technology such as ‘Virtual Reality’ (VR) can help as a method to form a new experience of ‘Extended Reality’ (XR) thereby acting as a design tool that engages human users as active participants in the design process (Stals & Caldas., 2022; Van Leeuwen et al., 2018). The use of XR in the design of vertical social spaces can enable a strategic intervention approach that identifies specific opportunities, selecting a set of improvements, avoiding mistakes, and prioritising the design actions that enhance the quality of the vertical urban space (Figure 8.9). These new design actions could be tested and changed by the users in their real-time in their 'virtual world' and therefore inform design decisions. This can all be done before the 'real world' physical roof garden or refurbished roof space has been built and therefore improve on the design outcome and future user experience.

Moreover, it is imperative to recognise that the participatory co-design approach should not be viewed as a solitary endeavour but as a continuing process. As these spaces evolve and usage patterns shift over time, persistent dialogue and collaboration between stakeholders are essential to guarantee the spaces' continued relevance, attractiveness, and responsiveness to users' needs. The practice of routinely soliciting user feedback and incorporating it into design and management decisions can assist in the creation of dynamic and resilient elevated social spaces that continue to serve their communities effectively in the future.

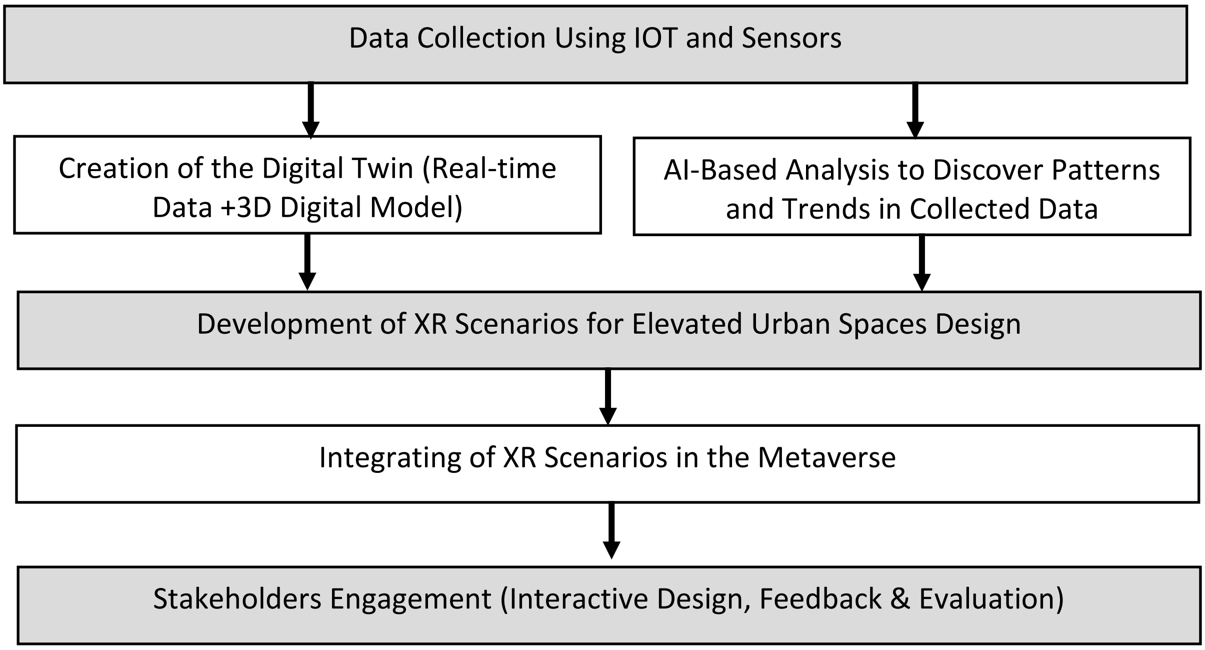


Figure 8.9: Conceptual Flow Chart for an Interactive Participatory Design model for Resilient Elevated Urban Spaces Design. Source: Author.

8.3 Virtual Study Discussion: A Comparative Analysis of Advanced Virtual Reality Co-Design Approaches

The aim of this study was to explore the implications of two distinct VR platforms—'Unreal Engine' and 'Enscape'—for architectural design and urban planning. By comparing their respective advantages, limitations, and opportunities, we have contributed to a broader understanding of how VR technologies can enhance the design process. Our findings align with existing literature (Van Leeuwen et al., 2017; Sanchez-Sepulveda et al., 2019; Meenar & Kitson, 2020), emphasising the transformative potential of immersive VR technology in decision-making and participatory design in architecture. In line with the experimental study conducted previously, our results demonstrate significant potential for utilising these novel methods as part of a collaborative approach for designing and refurbishing public spaces.

A significant majority of participants (87%; n=29) stated that using VR in architecture and urban design holds high potential as an effective design tool for communication between space users, clients, and designers. Importantly, most of the participants, irrespective of whether they had previously visited the gardens or had only experienced the gardens in VR, shared the same design concerns, limitations, and suggested features. This demonstrates the high capabilities of the VR systems used to capture the real environment for users.

A participant with prior visits to both the virtual and physical garden spaces remarked: *"Virtual reality revolutionises user involvement in architectural design, allowing pre-construction input. This pre-emptive interaction is vital, preventing post-build dissatisfaction and ensuring alignment between architectural intentions and user experiences".*

Although numerous previous studies have explored the use of various VR systems' capabilities within the fields of architecture and urban design, they emphasised knowledge gaps and the necessity for further examination of user behaviour and interaction in the virtual world when employing system capabilities to construct an interactive, participatory design approach (Jamei et al., 2017; Safikhani et al., 2022; Zhang et al., 2020). Our research is one of the initial studies examining participants' interactions with two distinct methods for developing interactive VR models, with the goal of integrating AI and VR into BIM (Figure 8.10).

An esteemed practitioner in architectural innovation proffered: *"The integration of Virtual Reality marks a paradigm shift in the interactive design process, presenting an exceptional* *level of realism and control. In the architectural domain, this innovation not only alleviates the financial and temporal exigencies associated with modifications post-construction but also bestows a sense of verisimilitude akin to physical occupancy of the space. The empowerment to manipulate design elements at one's behest within this immersive experience heralds a transformative era in architectural design, one that, in my considered opinion, is set to redefine our creative frontiers".*

Unreal Engine excels at creating visually realistic, high-fidelity models, which provides participants with an immersive experience closely mimicking the real world. This superior visual quality enables participants to thoroughly explore and assess design scenarios, deepening their understanding of spatial configurations and aesthetics (Panya et al., 2023; Khan et al., 2021). However, this platform requires exporting digital models from CAD software and necessitates proficiency in gaming engine software and programming languages such as C++ and Blueprints coding, which may limit its usability for architects and urban designers looking to create an interactive VR platform that allows users to change materials, move objects, and create dynamic lighting (Mack & Ruud, 2019; Prabhakaran et al., 2022; Rahimian et al., 2019). Furthermore, concerns were raised about Unreal Engine's limited teleportation VR method compared to Enscape.

In contrast, Enscape enables real-time design alterations due to its direct integration with Revit, making it more accessible to professionals who lack extensive programming knowledge (Safikhani et al., 2022; Davidson et al., 2020). Even though its graphical quality does not quite rival that of Unreal Engine, Enscape offers users a user-friendly interface and simpler navigation. However, these features may lead to increased motion sickness during the virtual experience due to different teleportation modes such as flying mode. Moreover, real-time interactivity allows users to effectively communicate and collaborate with other team members, streamlining the design process and promoting more efficient exploration of design scenarios (Schiavi et al., 2022; Ververidis et al., 2022).

The potential integration of emerging technologies such as AI and BIM with VR platforms presents intriguing possibilities for the future of architectural and urban design. Specifically, the combination of Enscape and VERAS offers an opportunity to utilise real-time data analysis, predictive modelling, and automated design generation within the virtual environment. These advancements could facilitate more informed decision-making, improve collaboration among team members, and enable seamless communication throughout the project lifecycle (Alizadehsalehi et al., 2020; Pan & Zhang, 2021, 2023).

Most participants (n = 27) identified the BIM method, utilising the Enscape and VERAS plugins, as the most effective approach for constructing an interactive design model in VR. The direct connection between the Revit model and the associated plugins facilitated real-time design modifications. These findings suggest that the strength of this approach lies not solely in the exceptional level of detail within the virtual model and the immersive experience that it provides, but also in the direct interaction and communication it fosters between the designer (investigator) and users (participants), as well as other project team members.

A veteran architect from the industry underscored: *"Integrating BIM with Enscape and VERAS in VR revolutionises our design workflow, enabling swift updates and a highly collaborative environment. This approach not only enriches our virtual models but also strengthens communication across the entire project team".*

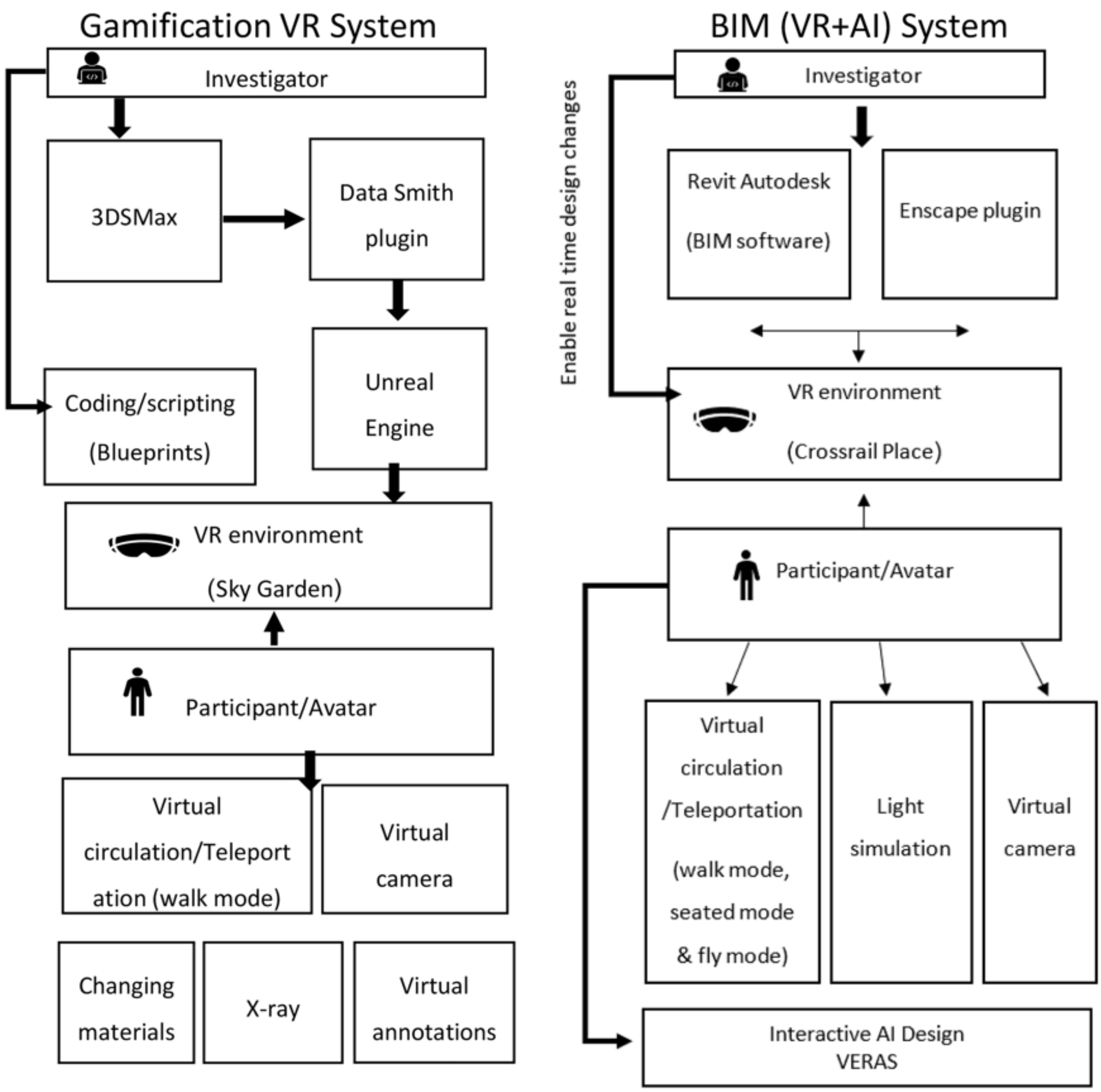


Figure 8.10: A schematic representation comparing the methodologies and processes involved in the creation of interactive VR models and participant engagement with interactive design features.. Source: Author.

8.4 Cross-Study Discussion from the Physical Cognitive Study and the Virtual Study

The findings of this study contribute to, and expand upon, the burgeoning body of literature emphasising the potential of VR as a tool for public engagement in sustainable urban design practice (Jamei et al., 2017; Meenar & Kitson, 2020). The comparative analysis conducted between real and virtual environments demonstrated that participants in both settings were effective in identifying design concerns and suggesting improvements. To further illuminate the similarities and differences between real environments and VR 3D models, it is crucial to note that both mediums endowed participants with a robust understanding of the spatial configuration and aesthetic qualities of the gardens. However, certain aspects of the real environment, such as sensory experiences (smell, touch, wind, temperature, etc.), and nuanced details (weathering effects, plant growth, etc.) could not be fully replicated in the VR 3D model. These differences have implications for how users perceive and interact with these spaces, influencing their observations and feedback.

A game designer, unfamiliar with the gardens in their physical form, offered a critical perspective on the sensory limitations of the virtual experience, asserting: *“The visual fidelity of virtual reality is commendable, yet it lacks the capacity to convey the tangible qualities of materials, such as the tactile feel of a leather chair. Enriching the virtual experience with haptic feedback would substantially deepen our understanding of material nuances, bolstering the efficacy of virtual reality as a vital asset in sustainable urban design practices and community engagement".*

In the realm of immersive experiences, the virtual environment has proven to be a catalyst for fostering a sense of freedom and confidence amongst participants. This digital milieu facilitates an explorative spirit, enabling individuals to venture beyond the confines of their habitual interactions and engage in activities that may seem daunting or inaccessible within the tangible world. A noteworthy segment of the study's participants (n=8) reflected on their experiences during the 2020 lockdown, illuminating the pivotal role that virtual reality can play as a social platform in times of global crises. These individuals acknowledged that while interacting with others through avatars in a virtual green space does not serve as a comprehensive substitute for the rich, cognitive stimulation provided by physical interactions, it does hold the potential to significantly alleviate the psychological strains of isolation. The consensus amongst these participants was that the integration of virtual reality into our social infrastructure could act as a vital support mechanism, mitigating the impacts of solitude on mental health and fostering a sense of connection and community during pandemics.

A participant and academic psychologist highlighted VR's potential in mental health care, stating*: "Virtual reality transcends traditional online tools like Teams, providing unparalleled immersion and social connection in digital spaces. It's invaluable for social VR platforms and mental health care advancement".*

A participant with academic credentials reflected on the transformative capabilities of VR, noting: *"VR offers enchanting possibilities, enabling actions beyond real-world constraints. This fusion of experiences cultivates unregulated behaviour, expanding our interaction paradigm".*

The VR 3D model, on the other hand, offered unique benefits that are not feasible in a real environment. For example, it allows for the manipulation of design elements and easy visualisation of alternative design scenarios, providing a dynamic tool for participatory design processes. This is consistent with previous research on the use of immersive technologies in urban design (Portman et al., 2015; Safikhani et al., 2022) and other studies where VR has been employed for various applications, such as simulating pedestrian experiences in urban environments (Sanchez-Sepulveda et al., 2019).

This study extends the existing literature by showcasing the effectiveness of VR in enabling real-time design modifications, fostering a more in-depth understanding of design challenges, and facilitating an interactive design process (Schrom-Feiertag et al., 2020; Zhang et al., 2021). Prior studies have largely focused on using VR for visualisation purposes, whereas this research emphasises the interactive aspect of VR, empowering users to actively engage with and modify the design of vertical green social spaces (Kim et al., 2020; Yu et al., 2018). By facilitating real-time modifications and providing an immersive understanding of design challenges, VR has the potential to serve as a powerful tool for designers and policymakers, playing a key role in the creation of more sustainable and inclusive cities.

The unique approach of incorporating both groups of participants – those who had physically visited the gardens and those who had not – offers valuable insights into the potential of VR as a co-design tool for public spaces. This methodology thus contributes to the broader discourse on inclusive and participatory urban design processes. The capacity of VR to engage diverse stakeholders in the design process, irrespective of their prior experience with the physical spaces, contributes to the ongoing exploration of innovative and sustainable solutions for towns and cities.

The experimental study's results demonstrated significant potential in utilising VR as a co-design approach for designing and refurbishing vertical green social spaces. Interestingly, the majority of participants (n=20) who had not physically visited the gardens successfully identified design limitations and concerns through the VR experiment. This allowed participants to suggest various activities and design features, empowering them in the design process. The design issues and needs discussed by this group closely aligned with the concerns and needs of actual space users who had previously been interviewed in both gardens. This suggests that the VR experiment effectively bridged the gap between the experiences of physical visitors and those who had not yet visited the spaces.

A seasoned architect participating in the study observed: *"Virtual reality isn't just a technological advancement; it's a democratic tool in architectural design. It allows potential space users to contribute meaningfully to the design process, addressing their needs and preventing potential design criticisms post-construction. Simultaneously, it provides architects with a creative sandbox to experiment and co-design with the end-users, ensuring a harmonious and functional space that aligns with users' expectations and needs".*

In addition, the study extends the application of VR beyond mere visualisation, positioning it as a co-design tool that fosters an inclusive, participatory design process. This implies that VR can democratise urban design by empowering diverse stakeholders to actively contribute to the design of public spaces. Inclusive design strategies are crucial to developing urban environments that are not only sustainable but genuinely responsive to the diverse needs and preferences of all users. Utilising VR technology highlights the long-term significance of design decisions, ultimately fostering the longevity and sustainability of public places by enabling stakeholders to efficiently address environmental, social, and economic considerations.

8.5 Implications of Findings

This section will revisit each research questions, aim and objective methodically, presenting in an exhaustive manner how the investigation has responded to each question and objective, whilst delving into the emergent implications of these findings. The implications in question primarily echo the impact of the study on urban design, planning, and architecture, especially in relation to London's elevated urban spaces. They particularly highlight the potential role and relevance of VR technology as a key player in the design and assessment of these spaces.

Investigations into the challenges faced by elevated social spaces in London, such as accessibility, people flow control, pinch points, user experience, and activities, have unveiled intricate facets that demand further consideration. The findings hold implications not only for the conception and development of future vertical social spaces but also for the reshaping and re-evaluating of existing spaces.

The performance analysis of proposed solutions for creating vertical social spaces that are safe, functional, and valuable for both users and developers has identified numerous strengths and shortcomings. These findings potentially inform the way stakeholders approach the design, management, and improvement of these spaces. More so, they can influence policy-making and implementation at a broader urban development scale.

Further, this study sheds light on the effectiveness of VR for evaluating elevated social spaces, as well as the value of integrating this technology in urban design processes. The practicality and reliability of VR as a co-design approach in this context, as derived from the findings, provide significant insights that can enhance the inclusion and representation of diverse user perspectives in the design of vertical social spaces.

Finally, the development of a comprehensive framework for designing London's vertical public realm to enable community engagement and participation implicates a shift in urban design and planning methodologies. This has the potential to enhance the social value of these spaces and promote a more democratic and inclusive urban development process.

Thus, the cumulative impact of the objectives signifies the core contribution of this research, encompassing both the theoretical and practical aspects of urban design, planning, and architecture, particularly concerning vertical social spaces in London. It also offers valuable insights that may be applied to other urban environments facing similar challenges, within the UK and internationally.

8.5.1 Research Question One & Objective One: Challenges and Factors Shaping Elevated Social Spaces in London

Addressing the intricate research question, *'How do various challenges and factors impact the design of elevated social spaces in London?*', this research meticulously unravelled the multifaceted dimensions influencing the conceptualisation and realisation of vertical urban spaces. By integrating insights from historical trajectories, global perspectives, and in-depth local analyses of London's elevated social spaces, the study not only identified the key challenges and factors at play but also formulated a robust set of design guidelines responsive to these intricacies. The journey from exploring the historical essence of London Garden Squares to investigating contemporary elevated spaces like Sky Garden and Crossrail Place, underscored the transformation and the persistent need for resilience in urban design. The research's comprehensive approach, spanning literature reviews, cognitive physical studies, and targeted discussions, ensured a holistic understanding, enabling the alignment of the findings with the initial objective. In doing so, it not only answered the central research question but also crafted a pathway for the development of adaptive and socially resilient elevated social spaces in the urban fabric of London.

The inaugural objective of this research was to critically discern the design qualities and determinants influencing the conceptualisation of elevated social spaces in London. The goal was to provide a set of guidelines for the adaptability and social resilience of vertical urban spaces. This thesis comprehensively accomplished this aim through extensive literature review presented in Chapters 2 and 3, a cognitive physical study in Chapter 6, and a culminating discussion in Section 8.1. The latter serves to spotlight guiding principles inherent in the planning of resilient elevated urban spaces.

The research initiated with an examination of London's private public spaces' historical trajectory, offering broader context on the evolution and administration of such spaces. Of paramount importance in this exploration was the history of London's private public gardens, better known as London Garden Squares. These bear significant resemblance to contemporary elevated roof gardens. This led to discourse around the central determinants of elevated urban spaces in London, with a primary focus on London's urbanisation challenges and the requisite need for inclusive, resilient vertical urban spaces.

This review was extensively broadened to encompass a macroscopic, worldwide perspective on the history of elevated social spaces and vertical public realm. The focus here was the Singaporean approach to reinventing 'green streets in the sky'. Furthermore, the review also explored the effect of the Covid-19 pandemic on the design challenges of these spaces, highlighting the importance of biophilic design.

There was a more microscopic investigation of London's elevated social spaces, including sky gardens, roof gardens, elevated parks, sky courts, and elevated walkways. Each typology was seen to be governed by its unique set of rules and regulations. The literature pinpointed key issues and factors affecting their design, which were later investigated through cognitive physical studies of the Sky Garden and Crossrail Place.

Through the analysis of direct observations and 'walk-along' interviews, an in-depth understanding of the real-life cognitive experiences of visitors to the Crossrail Place and Sky Garden was developed. Key areas of examination included accessibility, circulation, activities, visitor limitations, and social distancing. The data was analysed to form a set of design guideline principles. These critical characteristics incorporate accessibility, efficient circulation, opportunities for social interaction and activity, a sense of safety and security, clearly defined publicness and territorial rights, competent management, and an emphasis on a participatory co-design approach.

8.5.2 Research Question Two & Objective Two: Examining the Covid-19 Impact on Design and Management of Elevated Social Spaces

In addressing the pressing and pertinent question of *'How has the Covid-19 pandemic impacted upon the design and management of elevated social spaces in London?'*, this research has made significant strides towards understanding the multifaceted challenges and transformations brought about by the pandemic. The meticulous observation of visitor behaviour, movement, and activities across various phases of the pandemic provided a comprehensive lens through which to view the evolution of elevated social spaces, offering a rare glimpse into the adaptability and resilience of these urban environments. This approach, grounded in direct observations and enriched by walk-along interviews, has yielded a wealth of data that speaks directly to the second objective of this study, providing critical insights into the design elements, spatial utilisation, and social interactions that characterise elevated social spaces in the face of unprecedented challenges. The findings, framed within the context of the global health crisis, offer a roadmap for future design and management practices, ensuring that elevated social spaces not only endure but thrive in the face of adversity. In meeting the objective, this research contributes to a broader understanding of urban resilience, emphasising the importance of adaptability, inclusiveness, and a participatory design approach in the creation of spaces that serve the diverse needs of urban populations.

The second principal aim of this research was to meticulously observe and scrutinise visitors' behavioural patterns, movement, and activities in two distinctive typologies of elevated social spaces, prior to, during, and post the Covid-19 pandemic. The attainment of this objective was closely intertwined with the cognitive physical experience study. This involved gathering data through both direct observation and walk-along interviews in two case studies: the Sky Garden and the Crossrail Place roof garden.

The application of direct observational study spanning from 2019 through to 2022, over a period of three years, was crucial to collate information and comprehend the evolution of the spatial experience concerning accessibility, circulation, and the activities being undertaken. This methodology facilitated a deep understanding of how the spatial experience evolved over time and in response to changing circumstances.

Walk-along interviews were conducted to delve deeper into the cognitive and physical experiences of space users, as well as to gauge the impact on social interactions and the factors that facilitate them. The rich data acquired through these interviews provided profound insight into the participants' experiences, contributing to a more comprehensive understanding of the factors influencing social interactions and activities within these elevated urban spaces.

The primary findings, as determined by the research objective, include: (i) a critical analysis of design elements such as accessibility from the ground level, visitor circulation, and activities occurring within the space; (ii) utilisation of space syntax analysis to examine and ensure safe social distancing for visitors; and (iii) proposed solutions for designing secure, adaptable vertical social spaces.

The research underscores that the evolving typologies and current conditions of elevated urban spaces in London necessitate the reconceptualisation and re-evaluation of traditional approaches. Effective management and regulations emerge as essential negotiation tools to dictate appropriate users, uses, and behaviours in high-density vertical social spaces and optimise space use over time. An extensive range of rules and regulations needs to be meticulously analysed to strike a balance between safety, adaptability, and inclusiveness, while considering public perceptions and users' comprehensive experiences.

In response to such challenges, strategic design guidance that enhances communication amongst diverse stakeholders, including the public, to facilitate the decision-making process and ultimately improve outcomes, is vital. This necessitates the exploration of new, efficient, and flexible approaches to understand, evaluate, and guide the design and management of evolving vertical urban spaces. Before substantial funds are committed to physical structures, engaging the public, consulting on design options, and gathering ideas are all essential components of the process.

The findings from this study underscore the importance of considering visitors' diverse needs and preferences in the future design of vertical social spaces and roof gardens in cities similar to London. Crucial issues such as accessibility, affordability, and the integration of activities that encourage social interaction and physical activity emerged as significant considerations for designing inclusive and welcoming roof gardens. The outcomes underscore the necessity of creating environments that foster physical and mental well-being, promote social interaction, and enhance a sense of publicness. A notable finding is the importance of an immersive, interactive co-design process in creating spaces that resonate with the visitors. In conclusion, the findings from the Sky Garden and Crossrail Place Roof Garden studies provide critical insights for the design and management of urban rooftop gardens, emphasising the need for more inclusive and collaborative design processes that leverage direct user feedback.

8.5.3 Research Question Three & Objective Three: Evaluating the Benefits and Challenges of Using VR in Architecture and Urban Design for Elevated Social Spaces

At the core of this investigation was the intricate research question: *'What are the benefits and challenges of using VR in architecture and urban design for the design of elevated social spaces in London?'*. Diving deep into both the practical and theoretical realms of VR enabled a multifaceted response to emerge. The synthesis of current literature alongside hands-on VR experiments brought to light the overarching benefits of VR, such as its ability to enhance participatory design and streamline decision-making processes. These positives were carefully weighed against the challenges, including VR-induced discomfort and the complexities tied to integration. This comprehensive exploration not only provided clear answers to the research question but also brought to life the essence of Objective Three. It underscored the pivotal role of VR in the future of designing and co-designing elevated social spaces, creating a harmonious link between the research question and the objective. This showcases the depth and breadth of the scholarly work undertaken, marking it as a cornerstone for future innovation in the field.

The third aim of this research was to authenticate and examine a proposed model which reflects the influence of an interactive VR experience in co-designing elevated social spaces. This aim was realised through the synthesis of literature in Chapter 4 and evaluated in the virtual experience study.

The comprehensive review of the literature offered an in-depth appraisal of the array of VR tools, applications, and software currently in use, illuminating the potentialities, challenges, and voids associated with their deployment in urban and public space design. The utilisation of VR as a design instrument was meticulously assessed, concentrating on its potential to augment the design process and promote community engagement. Furthermore, the literature explored and underscored the future of integrating gamification, VR, BIM, and AI into the processes of architectural and urban design. A particular focus was given to designing two interactive VR systems: one rooted in gamification techniques and another integrating VR into BIM software.

In order to further realise this objective, we designed and evaluated two interactive, immersive VR platforms involving a distinct group of participants (n=33). This allowed the research team to probe deeply into the influence of VR technology on participant experiences and interactions within the study. It also afforded us an opportunity to assess the effectiveness of the two methodologies employed across different virtual environments.

The VR experiment examined two different methods and tools for developing interactive design models. The first model was constructed using Building Information Modelling (BIM), applying 'Autodesk Revit' software along with the 'Enscape' plugin. The second model was designed using a game engine, with 'Unreal Engine' as the principal development platform. These methods were specifically chosen due to their unique abilities in building intuitive VR systems and high-fidelity models, offering a comprehensive platform for immersive and interactive virtual environments.

This research provides a granular understanding of the implications of using two different VR platforms for architectural and urban design projects. A comparative assessment of their respective advantages, constraints, and possibilities contributes to a wider understanding of how VR technologies can refine the design process, streamline decision-making, and facilitate participatory design.

While there were some limitations related to the generalisability of the findings, this research lays a solid foundation for the future exploration of more platforms and solutions to the identified constraints. These include addressing physical space limitations, reducing VR-induced discomfort, enhancing social interaction, and engaging the senses through multi-modal haptic devices.

Consequently, it is recommended that future development of architectural software should aim to integrate VR into a more intuitive design system. This new system should not require designers to acquire additional programming skills or to export digital models to other game engines. The implications of this research are clear in its potential to guide future investigations and the development of accessible, integrated VR solutions for the architectural and urban design communities.

Moreover, this research raises questions concerning the role of artificial intelligence (AI) in enhancing VR capabilities for real-time design and collaboration. This provides a fascinating area for future research. By addressing the limitations and capitalising on the opportunities for improvement, this research can significantly contribute to the advancement of VR technology in architectural and urban design, fundamentally transforming the design process and promoting a more inclusive, collaborative, and innovative approach that benefits both the profession and the communities they serve.

8.5.4 Research Question Four & Objective Four: Utilizing VR Technology for Community Feedback in Elevated Social Space Design

By focusing on the pivotal research question of *'How can VR technology be utilised to gather feedback from the community and stakeholders on the proposed design of elevated social spaces?'*, this research has meticulously uncovered the extensive capabilities of VR as a tool for community engagement and feedback collection in the realm of elevated social spaces. The detailed case studies of the Sky Garden and Crossrail Place, analysed both tangibly and virtually, have provided crucial insights into how VR can serve as a bridge between designers, stakeholders, and the community, ensuring a democratic approach to urban design.

The outcomes of this research not only affirm the effectiveness of VR in eliciting valuable feedback from diverse participants but also fulfil the fourth objective by contributing to the creation of a validated framework for developing elevated social spaces in London. This framework, rooted in participatory design and inclusive feedback mechanisms, leverages the unique advantages of VR to facilitate a more engaged, informed, and collaborative design process. The findings highlight the transformative potential of VR in enhancing community participation, improving design quality, and fostering social and economic sustainability in urban spaces, thereby fulfilling the objective and providing a comprehensive answer to the research question.

This concept took into account VR technologies and community engagement, the facets of which have been intricately discussed and achieved through different sections of this thesis. Initial foundations were laid in Chapters Three and Four, presenting a literary overview that established the rudiments for the framework's guidelines, highlighting the necessity for an in-depth comparative analysis of visitor behaviours. This analysis was focused on two case studies: the Sky Garden and the Crossrail Place, across both tangible and virtual realms. The comparative analysis of these studies accentuated the efficiency of the adopted methodology in fabricating an effective and participatory co-design approach, subsequently leading to a functional framework. The guidelines, principles, and the framework were introduced in Section 8.2, providing a structured approach towards planning resilient elevated urban spaces.

This research illuminates the potential of VR as an instrumental tool for participatory design within public space design. The participatory element was explored by juxtaposing participants' experiences and design feedback in both real-life and virtual environments. The findings underscored that VR-anchored design tools provide an indispensable platform for participatory design and user engagement, capacitating participants to dynamically explore, scrutinise, and propose alterations to public space design. This facet is paramount in the creation of public spaces that effectively cater to people’s needs, thus ensuring long-term social and economic sustainability.

Participants provided a wealth of insights into design issues and proposed features in both real-life and virtual environments, aiding in the enhancement of design quality, and fostering physical activity and social interaction. The utilisation of VR in interactive design exploration afforded participants an active role in the design process. This opened up avenues for creative exploration, allowing them to test and visualize their design suggestions in real-time. This immersive engagement facilitated a comprehensive understanding of design challenges and helped participants to adapt the design according to their individual needs and preferences.

Moreover, the study shed light on VR's potential as a social online platform during times of global crises such as pandemics. Participants acknowledged the inherent limitations of virtual socialisation in substituting physical experiences but simultaneously recognised VR's positive impact on mental health, particularly for those living in solitude during enforced lockdowns or pandemics. In summation, the research findings accentuate the merits of integrating VR into the participatory design process. It exhibits its capacity to effectively engage users, elevate design quality, and augment the overall functionality, longevity, and aesthetic appeal of public spaces.

8.6 Contribution to Knowledge

Central to this study is the innovative development of an immersive, interactive design model. Its validation and promotion as a co-design methodology for the creation of elevated social spaces constitutes a significant scholarly contribution, particularly in the realms of urban and architectural design. This research introduces and advocates for crucial tools, methodologies, and procedures imperative to the creation of an engaging co-design environment.

The notable theoretical discovery of this investigation lies in the consistent resonance found between participant responses in both the virtual and the physical realms. This finding underscores the effectiveness of the suggested model in accurately capturing the behavioural patterns, perceptions of place, and spatial needs in the virtual environment. Intriguingly, the data gathered in this digital setting bears a remarkable similarity to the findings from the physical cognitive studies, reinforcing a previously unidentified likeness.

The majority of the study's participants were capable of articulating their design apprehensions, identifying necessary activities, and delineating the design elements crucial for fostering social interactions. Furthermore, they were afforded the opportunity to empirically test their design hypotheses. This research validates the virtual teleportation technique as an effective method of simulating a true-to-life sense of scale, offering participants a realistic spatial navigation experience at human eye level. The range of interactive tools made available to participants allowed for real-time interaction with the space, marking a significant advancement in design practice.

This study is pioneering in its design of a workflow for the creation and comparison of two sophisticated virtual reality techniques. It aimed to elucidate and compare their proficiency in constructing an interactive, intuitive design model, fostering participant interaction, and bridging the divide between designers and space users.

Moreover, this is the first research to effectively integrate and combine Virtual Reality (VR) and Artificial Intelligence (AI) using a Building Information Modelling (BIM) software. This integration heralds an exciting, pioneering era in the architectural practice and industry. The potential of the digital twin in architectural design opens up an innovative research avenue, offering a plethora of creative design solutions and opportunities for public engagement in the design of resilient public spaces. This study underscores the transformative power of AI as a creative conceptual design tool and highlights the significant effectiveness of interactive VR in emulating human sensations and behaviour in the virtual realm. Furthermore, it broadens the horizon for exploration and imagination, empowering users to experiment with and experience their design preferences in collaboration with project designers within an immersive co-design environment.

8.6.1 Practical Contribution for Applied Urban Design Frameworks and Policy Makers

The results and insights distilled from the discussion section not only offer a comprehensive understanding of how the pandemic has altered the design and human experience of elevated social spaces, but also provide pragmatic design and planning considerations. These are succinctly captured within a robust framework as highlighted in section 8.2. This framework serves as a practical guide for architects, urban designers, stakeholders, and policy makers, supporting their efforts to cultivate high-quality, resilient elevated social spaces that are safe and foster human engagement and interaction.

In addition, the insights gleaned from this study can meaningfully contribute to and influence foundational urban frameworks applied in the UK context. Furthermore, they offer an essential compass for navigating the intricate design challenges posed by the new normal ushered in by the Covid-19 pandemic. The tangible and virtual experiences of visitors, thoroughly investigated and detailed in this research, can inform future guidelines for urban space design in response to similar pandemics or crises. The research results reinforce the need for urban design and planning to incorporate and accommodate for significant shifts in human behaviour induced by unforeseen global events. They call for a heightened emphasis on adaptability and flexibility in urban design, demanding that our cities be ready to evolve and respond to rapid changes in environmental, social, and health-related conditions. This research also lends credence to the importance of a participatory design approach in creating adaptive, resilient urban spaces that effectively respond to the needs of users.

Moreover, the integration of VR technology in the co-design process, as demonstrated in this study, offers a transformative approach to urban design and planning. By leveraging VR, architects, urban designers, and policy makers can enhance participatory design processes, fostering more meaningful engagement with users and stakeholders, and enabling real-time design exploration and adaptation. This approach could prove especially beneficial in conditions where physical interaction is limited or not possible, as was the case during the Covid-19 pandemic. The findings from this study provide a pathway for more effective integration of advanced technologies such as VR and AI into urban design and planning, thereby pushing the boundaries of what is possible within this field. They offer valuable insights into the potential of these technologies in enhancing the quality, inclusivity, and resilience of our urban spaces, making them more responsive to the changing needs of society.

Additionally, this study lends empirical evidence to support the importance of designing public spaces that enhance mental well-being, particularly in times of crisis. This finding can contribute to a paradigm shift in urban design and planning, prioritising mental health and well-being as key considerations in public space design. In conclusion, the research significantly contributes to applied urban design frameworks and policy-making by providing empirical insights and practical guidelines for designing adaptable, resilient, inclusive, and participatory elevated social spaces. The adoption of these findings and guidelines has the potential to dramatically reshape the urban landscape in the post-pandemic world, promoting healthier, safer, and more socially vibrant communities in the UK and beyond.

8.7 Limitations

The COVID-19 pandemic has significantly influenced and redefined the parameters of this study, precipitating considerable alterations in its primary aim and objectives during the initial six months of this doctoral research. The pandemic induced an array of effects on various elevated urban spaces, which culminated in their intermittent closures during lockdown periods and throughout other stages of the health crisis.

This evolving landscape underscored the necessity to shift the study's focus from the activation of the vertical public realm in London, to a pressing exploration of the resilience of elevated urban spaces and their design. The pandemic's disruptive effects also emphasized the critical need for employing an interactive, participatory design approach to unpack the complex challenges associated with designing these urban spaces. Consequently, the obstacles posed by COVID-19 have been transformed into a rich research opportunity for this study.

However, the pandemic has also posed significant challenges, particularly with respect to data collection. The imposition of new regulations on public spaces, illustrated by the example of Sky Garden, has added complexity to the research process. Restrictions such as prescribed visitation times that required advanced booking, occasionally up to three weeks in advance at certain periods, limitations on visitor numbers within a given timeslot to ensure social distancing, a maximum duration of three hours per visit, and a prohibition on multiple visits within the same day have all added unique challenges. Despite these impediments, the pandemic's influence on the reshaping of urban spaces has allowed this study to identify and address issues of urban resilience and design in a novel and meaningful way.

Another constraint intrinsic to this research pertains to the practical application of VR in the study. In constructing an immersive virtual environment for co-designing public spaces, several inherent limitations must be addressed. One significant challenge is providing a sufficient physical space for participants to navigate freely within the virtual realm. Although the current study employed a standard 'guardian' area, respondents indicated that a larger, open space would enhance the sense of realism. Omnidirectional treadmills have been proposed as a potential solution; however, their high costs and required training render them unsuitable for widespread public use (Keung et al., 2021; Hooks et al., 2020). Additionally, some participants experienced VR sickness symptoms attributable to hardware factors (e.g., display type, mode, time delay), content factors (e.g., graphics, task-related features), and human factors (e.g., personal responses to VR). Reducing VR sickness in future research is essential to ensure participant comfort and optimize the overall VR experience (Saredakis et al., 2020; Chang et al., 2020).

A further limitation concerns social interaction within the virtual environment. Participants expressed a desire to share their virtual experiences with others, underscoring the need for an enhanced collaborative design experience. While VR social applications are currently available, they often provide limited design tools and inferior CGI model quality, and lack direct links between architectural design software and social VR applications (Safikhani et al., 2022; Zaker & Coloma, 2018; Ehab et al., 2023). Addressing these concerns is vital for improving collaborative design experiences. For instance, integrating more advanced user interaction techniques, such as motion tracking technologies, could significantly enhance the VR experience by enabling more natural and intuitive interactions within the virtual environment (Jalal et al., 2019).

In addition, recognizing users' facial expressions, as suggested by research on active appearance models and neural network, could make VR environments more interactive and responsive, leading to a more immersive user experience (Cha & Im, 2022; Hsu et al., 2013). Haptic feedback remains a significant challenge in VR environments. Although existing VR systems deliver realistic visual and auditory feedback, haptic feedback is often lacking, limiting users' ability to interact within free and constrained spaces. The development of multimodal haptic devices could ameliorate this limitation; however, cost and accessibility barriers persist (Schneider et al., 2017; Gallace et al., 2022).

In this doctoral research, an appreciable total of 99 participants were engaged across three distinct studies: the Sky Garden walkalong interviews, the Crossrail Place walkalong interviews, and the VR study. For each of these studies, the sample size was fixed at 33 participants. This number, although representing a fair cross-section, might be regarded as a limitation, suggesting that further insights could be gleaned from a larger sample size. However, given the qualitative nature of this research, the insights and conclusions obtained, even with these smaller sample sizes, are expected to be substantive and significant. This view is reinforced by numerous scholarly articles in the field of interactive VR design that have leveraged similar or even smaller sample sizes to yield meaningful results (Li et al., 2015; Kim et al., 2021). To strengthen the study's findings and enhance their generalizability, future research should incorporate a larger, more diverse pool of participants. Expanding the sample size would facilitate a more comprehensive understanding of VR's potential as a co-design tool in urban design, particularly when designing and refurbishing vertical green social spaces.

Another constraint involves the lack of knowledge and expertise among designers in creating interactive VR models, as well as interoperability issues between 3D CAD software and VR platforms. Addressing these obstacles would render VR-based co-design more accessible to professionals. Furthermore, the time and financial requirements associated with designing realistic and interactive VR models may discourage professionals from adopting VR-based co-design methods, favouring traditional design approaches instead. Reducing these constraints is essential for promoting the use of VR in urban design.

Although this study offers valuable insights, it is essential to acknowledge certain limitations. Firstly, the research focused exclusively on two VR platforms, which might limit the generalizability of the findings. Future studies could investigate additional platforms, examining their respective advantages, limitations, and opportunities. Additionally, such studies may benefit from including a larger and more diverse group of participants to better understand the potential impact and usability of these technologies in various contexts. Secondly, constructing a fully immersive and interactive VR using these methods presents several challenges that need addressing to make this technology more accessible to a wider range of designers and the general public. The participants in our study identified four primary areas for improvement: physical space restrictions, VR-induced sickness, social interaction, and sensory stimulation. Physical space constraints were highlighted as a significant obstacle to VR experiences (Hooks et al., 2020; Nilsson et al., 2018) with participants favouring the exploration of open, expansive areas for a more authentic experience. Furthermore, our investigation indicated that limiting VR usage to 20-minute intervals and incorporating breaks during the activity could alleviate motion sickness (Saredakis et al., 2020; Keshavarz et al., 2022), while a hybrid teleportation approach might facilitate participants' safe exploration of their surroundings (Chang et al., 2020; Boletsis & Chasanidou, 2022).

The majority of the participants expressed an interest in sharing their virtual experiences via social VR applications (Jalo et al., 2023; McVeigh-Schultz et al., 2019), indicating that subsequent research should focus on establishing a direct connection between architectural design software and social VR applications to enhance collaborative design processes. Furthermore, the study participants displayed a propensity to interact with virtual objects through touch, grasping, and manipulation (Gallace, 2022; Yin et al., 2021), suggesting that developing multimodal haptic devices capable of replicating the properties of virtual or remote objects and accommodating human gestures could augment the immersive VR experience. Consequently, further research should explore solutions to these limitations, including the implementation of omnidirectional treadmills (Hooks et al., 2020), the development of strategies for minimizing VR-induced sickness (Saredakis et al., 2020; Chang et al., 2020) , the establishment of direct connections between architectural design software and social VR applications (Jalo et al., 2020), and the creation of multimodal haptic devices for sensory stimulation (Gallace, 2022; Yin et al., 2021) .

8.9 Directions for Future Research Work

As such, future research should focus on addressing the identified limitations by exploring larger sample sizes, improved VR experiences, and the role of artificial intelligence (AI) in augmenting users' ability to describe and design schemes in real-time. Moreover, future studies could consider the incorporation of sensing devices for collecting more refined physiological features in the virtual environment, respecting participant privacy and ethical considerations. Furthermore, the development of architectural software to integrate VR into intuitive design systems would help eliminate the need for designers to learn new programming skills or export models to other game engines. Consequently, this would make VR-based co-design more accessible and practical for urban design professionals. Finally, the exploration of combined VR and AR technologies could pave the way for more immersive and effective co-design processes. In such a mixed-reality scenario, real-time camera tracking would allow for a seamless integration of the real and virtual worlds, thus offering a more robust platform for co-design activities.

The impact of this study is evident in its potential to influence future research and the development of more accessible and integrated VR solutions for the architectural design and urban design community. By highlighting the areas for improvement and opportunities for each platform, this study provides a foundation for further exploration of VR technologies and their potential to transform the design process. Moreover, this research emphasizes the importance of considering user experience, social interaction, and sensory stimulation in the development of VR platforms for architectural design and urban planning. By addressing these aspects, future research could contribute to the development of more effective and engaging co-design process that benefit both designers and end-users. Lastly, this research raises questions about the role of artificial intelligence (AI) in enhancing VR capabilities for real-time design and collaboration. Future studies could investigate the potential of AI-driven VR tools in enabling designers, clients, and end-users to seamlessly collaborate and contribute to the urban design process.

References

Abbasnejad, B., Nepal, M. P., Ahankoob, A., Nasirian, A., & Drogemuller, R. (2021). Building Information Modelling (BIM) adoption and implementation enablers in AEC firms: a systematic literature review. Architectural Engineering and design management, 17(5-6), 411-433.

Abdelsalam, A. E. (2018). Sustainable Vertical Urbanism as a Design Approach to Change the Future of Hyper Density Cities. Journal of Advance Research in Mechanical & Civil Engineering, 5(7), 2208-379.

Abhari, M., Abhari, K., Drinkwine, M., & Sloan, J. (2021, July). Extended Reality (XR) Applications in Architectural Practice: Towards a Development Framework. In International Conference on Human-Computer Interaction (pp. 185-196). Springer, Cham.

Adams, D., & Hastings, E. M. (2001). Urban renewal in Hong Kong: Transition from development corporation to renewal authority. Land Use Policy, 18(3), 245-258.

Adhya, A. (2008). The public realm as a place of everyday urbanism: Learning from four college towns (Doctoral dissertation, University of Michigan).

Aelbrecht, P., & Stevens, Q. (Eds.). (2019). Public space design and social cohesion: An international comparison. Routledge.

Aelbrecht, P., & Stevens, Q. (Eds.). (2019). Public space design and social cohesion: An international comparison. Routledge.

Afrin, S., Chowdhury, F. J., & Rahman, M. M. (2021). COVID-19 pandemic: rethinking strategies for resilient urban design, perceptions, and planning. Frontiers in Sustainable Cities, 3, 668263.

Ahlfeldt, G. M., & Barr, J. (2022). Viewing urban spatial history from tall buildings. Regional science and urban economics, 94, 103618.

Akbari, P., Yazdanfar, S. A., Hosseini, S. B., & Norouzian-Maleki, S. (2021). Housing and mental health during outbreak of COVID-19. Journal of Building Engineering, 43, 102919.

Aleta, A., Meloni, S., & Moreno, Y. (2017). A multilayer perspective for the analysis of urban transportation systems. Scientific reports, 7(1), 1-9.

Alhusban, A. A., Alhusban, S. A., & Alhusban, M. A. (2022). How the COVID 19 pandemic would change the future of architectural design. Journal of Engineering, Design and Technology, 20(1), 339-357.

Al-Kodmany, K. (2011). Placemaking with tall buildings. Urban Design International, 16, 252-269.

Al-Kodmany, K. (2018). The vertical city: a sustainable development model. WIT press.

Al-Kodmany, K. (2018). Sustainability and the 21st century vertical city: A review of design approaches of tall buildings. Buildings, 8(8), 102.

Al-Kodmany, K. (2018). Planning guidelines for enhancing placemaking with tall buildings. ArchNet-IJAR: International Journal of Architectural Research, 12(2), 5.

Al-Kodmany, K., Xue, Q., & Sun, C. (2022). Reconfiguring Vertical Urbanism: The Example of Tall Buildings and Transit-Oriented Development (TB-TOD) in Hong Kong. Buildings, 12(2), 197.T

Ali, M. M., & Al-Kodmany, K. (2012). Tall buildings and urban habitat of the 21st century: a global perspective. Buildings, 2(4), 384-423

Alizadehsalehi, S., Hadavi, A., & Huang, J. C. (2020). From BIM to extended reality in AEC industry. Automation in Construction, 116, 103254.

Alizadehsalehi, S., & Yitmen, I. (2023). Digital twin-based progress monitoring management model through reality capture to extended reality technologies (DRX). Smart and Sustainable Built Environment.

Alizadehsalehi, S., Hadavi, A., & Huang, J. C. (2021). Assessment of AEC students' performance using BIM-into-VR. Applied Sciences, 11(7), 3225.

Al-Jundi, H. A., & Tanbour, E. Y. (2022). A framework for fidelity evaluation of immersive virtual reality systems. Virtual Reality, 26(3), 1103-1122.

Amado, M. P., Santos, C. V., Moura, E. B., & Silva, V. G. (2010). Public participation in sustainable urban planning. International journal of human and social sciences, 5(2), 102-108.

Amati, M. (2007). From a blanket to a patchwork: The practicalities of reforming the London green belt. Journal of Environmental Planning and Management, 50(5), 579-594.

Amati, M., & Yokohari, M. (2006). Temporal changes and local variations in the functions of London's green belt. Landscape and urban planning, 75(1-2), 125-142.

Amati, M., & Yokohari, M. (2007). The establishment of the London greenbelt: reaching consensus over purchasing land. Journal of Planning History, 6(4), 311-337.

Amerio, A., Brambilla, A., Morganti, A., Aguglia, A., Bianchi, D., Santi, F., ... & Capolongo, S. (2020). COVID-19 lockdown: housing built environment's effects on mental health. International journal of environmental research and public health, 17(16), 5973.

Andres, L., Bryson, J. R., & Moawad, P. (2021). Temporary urbanisms as policy alternatives to enhance health and well-being in the post-pandemic city. Current environmental health reports, 8, 167-176.

Andreucci, M. B., Loder, A., Brown, M., & Brajković, J. (2021). Exploring challenges and opportunities of biophilic urban design: Evidence from research and experimentation. Sustainability, 13(8), 4323.

Angelov, V., Petkov, E., Shipkovenski, G., & Kalushkov, T. (2020, June). Modern virtual reality headsets. In 2020 International congress on human-computer interaction, optimization and robotic applications (HORA) (pp. 1-5). IEEE.

Angrosino, M. (2007). Doing ethnographic and observational research. Sage.

Appold, S. and Yuen, B., 2007. Families in flats, revisited. Urban Studies, 44(3), pp.569-589.

Arnstein, S. R. (1969). A ladder of citizen participation. Journal of the American Institute of Planners, 35(4), 216-224.

Ashkanasy, N. M., Ayoko, O. B., & Jehn, K. A. (2014). Understanding the physical environment of work and employee behavior: An affective events perspective. Journal of Organizational Behavior, 35(8), 1169-1184.

Ashtari, N., Bunt, A., McGrenere, J., Nebeling, M., & Chilana, P. K. (2020, April). Creating augmented and virtual reality applications: Current practices, challenges, and opportunities. In Proceedings of the 2020 CHI conference on human factors in computing systems (pp. 1-13).

Astell-Burt, T., Feng, X., & Kolt, G. S. (2013). Mental health benefits of neighbourhood green space are stronger among physically active adults in middle-to-older age: evidence from 260,061 Australians. Preventive medicine, 57(5), 601-606.

Aukstakalnis, S. (2016). Practical augmented reality: A guide to the technologies, applications, and human factors for AR and VR. Addison-Wesley Professional.

Azuma, R. T. (1997). A survey of augmented reality. Presence: teleoperators & virtual environments, 6(4), 355-385.

Baduge, S. K., Thilakarathna, S., Perera, J. S., Arashpour, M., Sharafi, P., Teodosio, B., ... & Mendis, P. (2022). Artificial intelligence and smart vision for building and construction 4.0: Machine and deep learning methods and applications. Automation in Construction, 141, 104440.

Bahari, S. F. (2010). Qualitative versus quantitative research strategies: contrasting epistemological and ontological assumptions. Sains Humanika, 52(1).

Baghalzadeh Shishehgarkhaneh, M., Keivani, A., Moehler, R. C., Jelodari, N., & Roshdi Laleh, S. (2022). Internet of Things (IoT), Building Information Modeling (BIM), and Digital Twin (DT) in Construction Industry: A Review, Bibliometric, and Network Analysis. Buildings, 12(10), 1503.

Bailey, J., Bailenson, J. N., Won, A. S., Flora, J., & Armel, K. C. (2012, October). Presence and memory: immersive virtual reality effects on cued recall. In Proceedings of the International Society for Presence Research Annual Conference (pp. 24-26).

Banai, R. (2020). Pandemic and the planning of resilient cities and regions. Cities, 106, 102929.

Banerjee, T. (2001). The future of public space: beyond invented streets and reinvented places. Journal of the American planning association, 67(1), 9-24.

Bannon, L. J., & Ehn, P. (2012). Design: design matters in Participatory Design. In Routledge international handbook of participatory design (pp. 37-63). Routledge.

Bansal, K., Varshneya, H., Oldfield, P., 2017. The history of the skygarden: a chronological analysis of socio-communal spaces at height in tall buildings. In: 5th International Conference on Architecture and Civil Engineering (ACE 2017), pp. 25-32.

Barhorst, J. B., McLean, G., Shah, E., & Mack, R. (2021). Blending the real world and the virtual world: Exploring the role of flow in augmented reality experiences. Journal of Business Research, 122, 423-436.

Barthes, R. (2012). The Eiffel Tower. AA Files, (64), 112-131.

Barton, H., & Grant, M. (2013). Urban planning for healthy cities: A review of the progress of the European Healthy Cities Programme. Journal of urban health, 90, 129-141.

Batty, M. (2018). Inventing future cities. MIT Press.

Baum, A., & Paulus, P. B. (1987). Crowding. In D. Stokols & I. Altman (Eds.), Handbook of environmental psychology (Vol. 1, pp. 533-570). Wiley

Baxter, P., & Jack, S. (2008). Qualitative case study methodology: Study design and implementation for novice researchers. The qualitative report, 13(4), 544-559.

Bay, J. H. (2004). Sustainable community and environment in tropical Singapore high-rise housing: the case of Bedok Court condominium. ARQ: Architectural Research Quarterly, 8(3-4), 333-343.

Bay, J. H. P., & Lehmann, S. (Eds.). (2017). Growing compact: Urban form, density and sustainability. Taylor & Francis.

Bayulken, B., & Huisingh, D. (2015). A literature review of historical trends and emerging theoretical approaches for developing sustainable cities (part 1). Journal of Cleaner Production, 109, 11-24.

Bazjanac, V. (2006). Virtual building environments (VBE)-applying information modeling to buildings. August, 29, 2009.

Bednarska-Olejniczak, D., Olejniczak, J., & Svobodová, L. (2019). Towards a smart and sustainable city with the involvement of public participation—The case of Wroclaw. Sustainability, 11(2), 332.

Bell, E., & Bryman, A. (2007). The ethics of management research: an exploratory content analysis. British journal of management, 18(1), 63-77.

Bereitschaft, B., & Scheller, D. (2020). How might the COVID-19 pandemic affect 21st century urban design, planning, and development?. Urban Science, 4(4), 56.

Berg, L. P., & Vance, J. M. (2017). Industry use of virtual reality in product design and manufacturing: a survey. Virtual reality, 21, 1-17.

Berman, M. G., Kross, E., Krpan, K. M., Askren, M. K., Burson, A., Deldin, P. J., ... & Jonides, J. (2012). Interacting with nature improves cognition and affect for individuals with depression. Journal of affective disorders, 140(3), 300-305.

Bernstein, P. G. (2018). Architecture| Design| Data. In Architecture| Design| Data. Birkhäuser.

Beveridge, C. E., & Rocheleau, P. (1995). Frederick Law Olmsted. New York, NY, USA: Rizzoli International Publications.

Beyan, E. V. P., & Rossy, A. G. C. (2023). A Review of AI Image Generator: Influences, Challenges, and Future Prospects for Architectural Field. Journal of Artificial Intelligence in Architecture, 2(1), 53-65.

Bhaskar, R. (2013). A Realist Theory of Science. Routledge.

Bibri, S. E. (2020). Compact urbanism and the synergic potential of its integration with data-driven smart urbanism: An extensive interdisciplinary literature review. Land Use Policy, 97, 104703.

Bibri, S. E., & Krogstie, J. (2017). Smart sustainable cities of the future: An extensive interdisciplinary literature review. Sustainable cities and society, 31, 183-212.

Biecek, P., & Burzykowski, T. (2021). Explanatory model analysis: explore, explain, and examine predictive models. CRC Press.

Billinghurst, M., & Kato, H. (2002). Collaborative augmented reality. Communications of the ACM, 45(7), 64-70.

Binder, T., & Brandt, E. (2008). The Design: Lab as platform in participatory design research. Co-design, 4(2), 115-129.

Bischeri, C., & Micheli, S. (2016). New directions for the dense city: Moshe Safdie in Singapore. Joelho-Journal of Architectural Culture, (7), 116-131.

Bjögvinsson, E., Ehn, P., & Hillgren, P. A. (2012). Design things and design thinking: Contemporary participatory design challenges. Design issues, 28(3), 101-116.

Blaikie, N. (2007). Approaches to social enquiry: Advancing knowledge. Polity.

Blaikie, N. (2004). Epistemology. In M.S. Lewis-Beck. A. Bryman. and T.F. Liao (Eds.), The SAGE Encyclopaedia of Social Science Research Methods. Sage Knowledge. http://dx.doi.org/10.4135/9781412950589.n281

Blaikie, N. W. (1991). A critique of the use of triangulation in social research. Quality and quantity, 25(2), 115-136.

Blomkamp, E. (2018). The promise of co-design for public policy. Australian journal of public administration, 77(4), 729-743.

Bodnar, J. (2015). Reclaiming public space. Urban studies, 52(12), 2090-2104.

Boesiger, W., & Girsberger, H. (2000). Le Corbusier 1910-65. Barcelona, Spain: Editorial Gustavo Gili.

Bohman, J. (2004). Expanding dialogue: The Internet, the public sphere and prospects for transnational democracy. The sociological review, 52(1_suppl), 131-155.

Bojović, M., Rajković, I., & Perović, S. K. (2022). Towards resilient residential buildings and neighborhoods in light of covid-19 pandemic—The scenario of Podgorica, Montenegro. Sustainability, 14(3), 1302.

Boletsis, C., & Chasanidou, D. (2022). A Typology of Virtual Reality Locomotion Techniques. Multimodal Technologies and Interaction, 6(9), 72.

Borda, O. F. (2006). Participatory (action) research in social theory: Origins and challenges. Handbook of action research: Participative inquiry and practice, 3, 27-37.

Borgstrom, E., & Barclay, S. (2019). Experience-based design, co-design and experience-based co-design in palliative and end-of-life care. BMJ supportive & palliative care, 9(1), 60-66.

Borowski, E., & Stathopoulos, A. (2023). Nowhere to go? A study of marginalization, social connection, and mental health outcomes among young adults experiencing the COVID-19 pandemic. Journal of Transport & Health, 101589.

Bosetti, N., Brown, R., Belcher, E. & Washington-Ihieme, M., 2019. Public London: the regulation, management and use of public spaces, London: Published by Centre for London.

Botero, A., & Hyysalo, S. (2013). Ageing together: Steps towards evolutionary co-design in everyday practices. CoDesign, 9(1), 37-54.

Boyle, D., & Harris, M. (2009). The challenge of co-production. London: new economics foundation, 56, 18.

Bozzelli, G., Raia, A., Ricciardi, S., De Nino, M., Barile, N., Perrella, M., ... & Palombini, A. (2019). An integrated VR/AR framework for user-centric interactive experience of cultural heritage: The ArkaeVision project. Digital Applications in Archaeology and Cultural Heritage, 15, e00124.

Brain, D. (2019). Reconstituting the urban commons: Public space, social capital and the project of urbanism. Urban Planning, 4(2), 169-182.

Brandt, E., Binder, T., & Sanders, E. B. N. (2012). Tools and techniques: Ways to engage telling, making and enacting. In Routledge international handbook of participatory design (pp. 145-181). Routledge.

Brandt, E., Messeter, J., & Binder, T. (2008). Formatting design dialogues–games and participation. Co-Design, 4(1), 51-64.

Bridge, G., 2002. The neighbourhood and social networks. CNR paper 4, School of Policy studies, Centre for Neighbourhood Research, Bristol University, pp.1-32.

Brill, M., 1989. Transformation, nostalgia, and illusion in public life and public place. In Public places and spaces (pp. 7-29). Springer, Boston, MA.

Brimblecombe, P. (2012). The big smoke (Routledge Revivals): A history of air pollution in London since medieval times. Routledge.

Brinkmann, S. (2013). Qualitative interviewing. Oxford university press.

Brown, T., & Wyatt, J. (2010). Design thinking for social innovation. Development Outreach, 12(1), 29-43.

Brownstone, D., & Golob, T. F. (2009). The impact of residential density on vehicle usage and energy consumption. Journal of Urban Economics, 65(1), 91-98.

Bryman, A. (2016). Social research methods. Oxford university press.

Bucher, J. (2017). Storytelling for virtual reality: methods and principles for crafting immersive narratives. Routledge.

Burton, P. (2009). Conceptual, theoretical and practical issues in measuring the benefits of public participation. Evaluation, 15(3), 263-284.

Bussell, C., Ehab, A., Hartle-Ryan, D., & Kapsalis, T. (2023, July). Generative AI for Immersive Experiences: Integrating Text-to-Image Models in VR-Mediated Co-design Workflows.

In International Conference on Human-Computer Interaction (pp. 380-388). Cham: Springer Nature Switzerland.

Butina, M., Campbell, S., & Miller, W. (2015). Conducting qualitative research introduction. Clinical Laboratory Science, 28(3), 186-189.

Caetano, I., Santos, L., & Leitão, A. (2020). Computational design in architecture: Defining parametric, generative, and algorithmic design. Frontiers of Architectural Research, 9(2), 287-300.

Calhoun, C. (2011). Habermas and the public sphere. Cambridge, Mass, MIT Press.

Calvo, M., & Sclater, M. (2021). Creating spaces for collaboration in community co-design. International Journal of Art & Design Education, 40(1), 232-250.

Campbell, K. (2001). Rethinking open space, open space provision and management: a way forward. Report presented by Scottish Executive Central Research Unit, Edinburgh.

Caperchione, E., Demirag, I., & Grossi, G. (2017, April). Public sector reforms and public private partnerships: Overview and research agenda. In Accounting Forum (Vol. 41, No. 1, pp. 1-7). No longer published by Elsevier.

Carlsson, G., Slaug, B., Schmidt, S. M., Norin, L., Ronchi, E., & Gefenaite, G. (2022). A scoping review of public building accessibility. Disability and Health Journal, 15(2), 101227.

Carmigniani, J., & Furht, B. (2011). Augmented reality: an overview. Handbook of augmented reality, 3-46.

Carmona, M. (2019). Place value: Place quality and its impact on health, social, economic and environmental outcomes. Journal of urban design, 24(1), 1-48.

Carmona, M., de Magalhães, C. and Hammond, L. eds., 2008. Public space: the management dimension. Routledge.

Carmona, M., Heath, T., Tiesdell, S., and Oc, T., 2010. Public places, urban spaces: the dimensions of urban design. Routledge.

Carmona, M. (2010). Contemporary public space: Critique and classification, part one: Critique. Journal of urban design, 15(1), 123-148.

Carmona, M. (2010). Contemporary public space, part two: Classification. Journal of urban design, 15(2), 157-173.

Carmona, M. (2015). Re-theorising contemporary public space: a new narrative and a new normative. Journal of Urbanism: International Research on Placemaking and Urban Sustainability, 8(4), 373-405.

Carmona, M., & Wunderlich, F. (2013). Capital spaces: the multiple complex public spaces of a global city. Routledge.

Carmona, M. (2019). Principles for public space design, planning to do better. Urban Design International, 24(1), 47-59.

Carmona, M. (2021). Public places urban spaces: The dimensions of urban design. Routledge.

Carmona, M. (2022). The “public-isation” of private space–towards a charter of public space rights and responsibilities. Journal of Urbanism: International Research on Placemaking and Urban Sustainability, 15(2), 133-164.

Carpiano, R. M. (2009). Come take a walk with me: The “Go-Along” interview as a novel method for studying the implications of place for health and well-being. Health & place, 15(1), 263-272.

Carr, S., Francis, M., Rivlin, L. G., & Stone, A. M. (1992). Public space. Cambridge University Press.

Carroll, S., & Nørtoft, K. (2022). Co-designing age-friendly neighborhood spaces in Copenhagen: Starting with an age-friendly co-design process. Architecture, 2(2), 214-230.

Caserman, P., Garcia-Agundez, A., Konrad, R., Göbel, S., & Steinmetz, R. (2019). Real-time body tracking in virtual reality using a Vive tracker. Virtual Reality, 23, 155-168.

Casini, M. (2022). Extended Reality for Smart Building Operation and Maintenance: A Review. Energies, 15(10), 3785.

Cassegård, C. (2014). Contestation and bracketing: The relation between public space and the public sphere. Environment and Planning D: Society and Space, 32(4), 689-703

Calvo, X., Fonseca, D., Sánchez-Sepúlveda, M., Amo, D., Llorca, J., & Redondo, E. (2018). Programming virtual interactions for gamified educational proposes of urban spaces. In Learning and Collaboration Technologies. Learning and Teaching: 5th International Conference, LCT 2018, Held as Part of HCI International 2018, Las Vegas, NV, USA, July 15-20, 2018, Proceedings, Part II 5 (pp. 128-140). Springer International Publishing.

Cavalcanti, J., Valls, V., Contero, M., & Fonseca, D. (2021). Gamification and hazard communication in virtual reality: A qualitative study. Sensors, 21(14), 4663

Cervero, R., & Murakami, J. (2010). Effects of built environments on vehicle miles traveled: evidence from 370 US urbanized areas. Environment and Planning A, 42(2), 400-418.

Chadios, K. (2005). The urban coffee shop (Doctoral dissertation, Massachusetts Institute of Technology).

Champagne, M. P., Dubé, J., & Barla, P. (2022). Build it and they will come: How does a new public transit station influence building construction?. Journal of Transport Geography, 100, 103320.

Chang, E., Kim, H. T., & Yoo, B. (2020). Virtual reality sickness: a review of causes and measurements. International Journal of Human–Computer Interaction, 36(17), 1658-1682.

Chatterjee, M., 2009. Perception of housing environment among high rise dwellers. Journal of the Indian Academy of Applied Psychology, 35(8).

Chen, S. E. (1995, September). Quicktime VR: An image-based approach to virtual environment navigation. In Proceedings of the 22nd annual conference on Computer graphics and interactive techniques (pp. 29-38).

Chen, T. L., Chiu, H. W., & Lin, Y. F. (2020). How do east and southeast Asian cities differ from western cities? A systematic review of the urban form characteristics. Sustainability, 12(6), 2423.

Cheng, Z., Wang, H., Xiong, W., Zhu, D., & Cheng, L. (2021). Public–private partnership as a driver of sustainable development: Toward a conceptual framework of sustainability-oriented PPP. Environment, Development and Sustainability, 23, 1043-1063.

Cheshmehzangi, A. (2020). 10 adaptive measures for public places to face the COVID 19 pandemic outbreak. City & Society (Washington, DC), 32(2).

Chettri, L., & Bera, R. (2019). A comprehensive survey on Internet of Things (IoT) toward 5G wireless systems. IEEE Internet of Things Journal, 7(1), 16-32.

Chevalier, J. M., & Buckles, D. J. (2019). Participatory action research: Theory and methods for engaged inquiry. Routledge.

Childs, M.C., 2006. Squares: A public place design guide for urbanists. University of New Mexico Press.

Cho, I. S. (2019). Urban Space Design for Hybrid and High-Density Environments. In The New Companion to Urban Design (pp. 218-228). Routledge.

Cho, I. S., Heng, C. K., & Trivic, Z. (2015). Re-framing urban space: urban design for emerging hybrid and high-density conditions. Routledge.

Cho, I. S. (2022). Fostering Community Bonding in High-Density Habitations. Future Urban Habitation: Transdisciplinary Perspectives, Conceptions, and Designs, 149-163.

Cho, I. S., Trivic, Z., & Nasution, I. (2017). New high-density intensified housing developments in Asia: qualities, potential and challenges. Journal of Urban Design, 22(5), 613-636.

Churchman, A., 1999. Disentangling the concept of density. Journal of planning literature, 13(4), pp.389-411.

Chui, M., Loffler, M., & Roberts, R. (2010). The internet of things. McKinsey Global Institute.

Cohen-Cline, H., Turkheimer, E., & Duncan, G. E. (2015). Access to green space, physical activity and mental health: a twin study. J Epidemiol Community Health, 69(6), 523-529.

Cohen, J. L. (2004). Le Corbusier, 1887-1965: The Lyricism of Architecture in the Machine Age. Taschen.

Conroy, R. (2001). Spatial navigation in immersive virtual environments. University of London, University College London (United Kingdom).

Cook, M., Lischer-Katz, Z., Hall, N., Hardesty, J., Johnson, J., McDonald, R., & Carlisle, T. (2019). Challenges and strategies for educational virtual reality. Information Technology and Libraries, 38(4), 25-48.

Cooper, N., Milella, F., Pinto, C., Cant, I., White, M., & Meyer, G. (2018). The effects of substitute multisensory feedback on task performance and the sense of presence in a virtual reality environment. PloS one, 13(2), e0191846.

Corbetta, P. (2003). Social research: Theory, methods and techniques. Sage Publications.

Corburn, J. (2017). Urban place and health equity: critical issues and practices. International journal of environmental research and public health, 14(2), 117.

Corbusier, L. (2013). Towards a new architecture. Courier Corporation.

Cowan, B. (2004). Mr. Spectator and the coffeehouse public sphere. Eighteenth-Century Studies, 345-366.

Crawford, M. (2021). Blurring the boundaries: public space and private life. In Public Space Reader (pp. 26-33). Routledge.

Cresswell, J. W. (1998). Qualitative inquiry and research design: Choosing among five traditions.

Creswell, J. W. (2013). Steps in conducting a scholarly mixed methods study.

Creswell, J. W., & Creswell, J. D. (2017). Research design: Qualitative, quantitative, and mixed methods approaches. Sage publications.

Creswell, J. W., & Poth, C. N. (2016). Qualitative inquiry and research design: Choosing among five approaches. Sage publications.

Crofton, E. C., Botinestean, C., Fenelon, M., & Gallagher, E. (2019). Potential applications for virtual and augmented reality technologies in sensory science. Innovative Food Science & Emerging Technologies, 56, 102178.

Crotty, M. J. (1998). The foundations of social research: Meaning and perspective in the research process. The foundations of social research, 1-256.

Cruickshank, L., Coupe, G., & Hennessy, D. (2013). Co-Design: fundamental issues and guidelines for designers: Beyond the Castle Case Study. Swedish Design Research Journal, 10, 48-57.

Cruz-Neira, C., Fernández, M., & Portalés, C. (2018). Virtual reality and games. Multimodal Technologies and Interaction, 2(1), 8.

Cullen, G. 1961. Townscape, London: Architectural Press.

Cummings, J. J., & Bailenson, J. N. (2016). How immersive is enough? A meta-analysis of the effect of immersive technology on user presence. Media psychology, 19(2), 272-309.

Cuthbertson, L. M., Robb, Y. A., & Blair, S. (2020). Theory and application of research principles and philosophical underpinning for a study utilising interpretative phenomenological analysis. Radiography, 26(2), e94-e102.

Cypress, B. S. (2015). Qualitative research: the “what,”“why,”“who,” and “how”!. Dimensions of Critical Care Nursing, 34(6), 356-361.

Dalley, S. (1994). Nineveh, Babylon and the Hanging Gardens: cuneiform and classical sources reconciled1. Iraq, 56, 45-58.

Darko, A., Chan, A. P., Adabre, M. A., Edwards, D. J., Hosseini, M. R., & Ameyaw, E. E. (2020). Artificial intelligence in the AEC industry: Scientometric analysis and visualization of research activities. Automation in Construction, 112, 103081.

David, A., Joy, E., Kumar, S., & Bezaleel, S. J. (2022). Integrating Virtual Reality with 3D Modeling for Interactive Architectural Visualization and Photorealistic Simulation: A Direction for Future Smart Construction Design Using a Game Engine. In Second International Conference on Image Processing and Capsule Networks: ICIPCN 2021 2 (pp. 180-192). Springer International Publishing.

Davidson, J., Fowler, J., Pantazis, C., Sannino, M., Walker, J., Sheikhkhoshkar, M., & Rahimian, F. P. (2020). Integration of VR with BIM to facilitate real-time creation of bill of quantities during the design phase: A proof of concept study. Frontiers of Engineering Management, 7, 396-403.

Day, K., Alfonzo, M., Chen, Y., Guo, Z., & Lee, K. K. (2013). Overweight, obesity, and inactivity and urban design in rapidly growing Chinese cities. Health & place, 21, 29-38.

De Amicis, R., Riggio, M., Shahbaz Badr, A., Fick, J., Sanchez, C. A., & Prather, E. A. (2019). Cross-reality environments in smart buildings to advance STEM cyberlearning. International Journal on Interactive Design and Manufacturing (IJIDeM), 13, 331-348.

De Lange, M., & De Waal, M. (2017). Owning the city: New media and citizen engagement in urban design. In Urban land use (pp. 109-130). Apple Academic Press.

Delgado, J. M. D., Oyedele, L., Demian, P., & Beach, T. (2020). A research agenda for augmented and virtual reality in architecture, engineering and construction. Advanced Engineering Informatics, 45, 101122.

Della Porta, D., & Keating, M. (Eds.). (2008). Approaches and methodologies in the social sciences: A pluralist perspective. Cambridge University Press.

De Magalhães, C., 2010. Public space and the contracting-out of publicness: A framework for analysis. Journal of Urban Design, 15(4), pp.559-574.

De Magalhaes, C., & Trigo, S. F. (2017). Contracting out publicness: The private management of the urban public realm and its implications. Progress in Planning, 115, 1-28.

De Magalhães, C., & Carmona, M. (2009). Dimensions and models of contemporary public space management in England. Journal of Environmental Planning and Management, 52(1), 111-129.

Denzin, N. K. (2018). The qualitative manifesto: A call to arms. Routledge.

Denzin, N. K., & Lincoln, Y. S. (Eds.). (2011). The Sage handbook of qualitative research. sage.

depthmapX development team. (2017). depthmapX (Version 0.6.0) [Computer software]. Retrieved from https://github.com/SpaceGroupUCL/depthmapX/

Desa, U.N., 2015. World Urbanization Prospects: The 2014 Revision. United Nations Department of Economics and Social Affairs, Population Division: New York, 41.

De Siqueira, G., Malaj, S., & Hamdani, M. (2022). Digitalization, Participation and Interaction: Towards More Inclusive Tools in Urban Design—A Literature Review. Sustainability, 14(8), 4514.

Deterding, S. (2019). Gamification in management: Between choice architecture and humanistic design. Journal of Management Inquiry, 28(2), 131-136.

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011, September). From game design elements to gamefulness: defining" gamification". In Proceedings of the 15th international academic MindTrek conference: Envisioning future media environments (pp. 9-15).

Deutsche, R., 1992. Art and public space: Questions of democracy. Social Text, (33), pp.34-53.

Devereux, M., & Littlefield, D. (2017). A literature review on the privatisation of public space.

Dianati, K., Zimmermann, N.Z. and Davies, M.D., 2017, September. London's Housing Crisis. System Dynamics Society.

DiCicco-Bloom, B., & Crabtree, B. F. (2006). The qualitative research interview. Medical education, 40(4), 314-321.

Dickenson, C. P. (2016). On the Agora: The Evolution of a Public Space in Hellenistic and Roman Greece (c. 323 BC–267 AD). In On the Agora. Brill.

Dictionary, C. E. (2014). Collins English dictionary. Complete and Unabridged.

Dillman, D. A., Smyth, J. D., & Christian, L. M. (2014). Internet, phone, mail, and mixed-mode surveys: The tailored design method. John Wiley & Sons.

Di Marino, M., Tabrizi, H. A., Chavoshi, S. H., & Sinitsyna, A. (2022). Hybrid cities and new working spaces–The case of Oslo. Progress in Planning, 100712.

Diener, E., & Crandall, R. (1978). Ethics in social and behavioral research. U Chicago Press.

Dong, T., Jiao, L., Xu, G., Yang, L., & Liu, J. (2019). Towards sustainability? Analyzing changing urban form patterns in the United States, Europe, and China. Science of the Total Environment, 671, 632-643.

Dougherty Jr, G. W., & Easton, J. (2011). Appointed public volunteer boards: Exploring the basics of citizen participation through boards and commissions. The American Review of Public Administration, 41(5), 519-541.

Douglas, M., Katikireddi, S. V., Taulbut, M., McKee, M., & McCartney, G. (2020). Mitigating the wider health effects of covid-19 pandemic response. Bmj, 369.

Dudovskiy, J. (2016). The ultimate guide to writing a dissertation in business studies: a step-by-step assistance, July 2016 edition. eBook Journal of Mixed Methods Research, 4(1), 6-16.

Dwivedi, Y. K., Hughes, L., Baabdullah, A. M., Ribeiro-Navarrete, S., Giannakis, M., Al-Debei, M. M., ... & Wamba, S. F. (2022). Metaverse beyond the hype: Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. International Journal of Information Management, 66, 102542.

Dworski-Riggs, D., & Langhout, R. D. (2010). Elucidating the power in empowerment and the participation in participatory action research: A story about research team and elementary school change. American journal of community psychology, 45, 215-230.

Eastman, C. M., Teicholz, P., Sacks, R., & Liston, K. (2011). BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors. John Wiley & Sons.

Edwards, B. (2011). Sustainability and the design of transport interchanges. Routledge.

Edwards, B. C. (2013). London Docklands: urban design in an age of deregulation. Elsevier.

Ehab, A., Burnett, G., & Heath, T. (2023). Enhancing Public Engagement in Architectural Design: A Comparative Analysis of Advanced Virtual Reality Approaches in Building Information Modeling and Gamification Techniques. Buildings, 13(5), 1262. https://doi.org/10.3390/buildings13051262

Ehab, A., & Heath, T. (2023). Exploring Immersive Co-Design: Comparing Human Interaction in Real and Virtual Elevated Urban Spaces in London. Sustainability, 15(12), 9184. https://doi.org/10.3390/su15129184

Ehab, A., Heath, T., & Burnett, G. (2023, July). Virtual Reality and the Interactive Design of Elevated Public Spaces: Cognitive Experience vs VR Experience. In International Conference on Human-Computer Interaction (pp. 176-184). Cham: Springer Nature Switzerland.

El-Jarn, H., & Southern, G. (2020). Can co-creation in extended reality technologies facilitate the design process?. Journal of Work-Applied Management, 12(2), 191-205.

Ellin, N. (2013). Integral urbanism. Routledge.

Elton, C. S. (2012). The pattern of animal communities. Springer Science & Business Media.

Eisenman, T. S. (2013). Frederick Law Olmsted, green infrastructure, and the evolving city. Journal of planning history, 12(4), 287-311.

Eraydin, A. (2012). "Resilience thinking" for planning. In Resilience thinking in urban planning (pp. 17-37). Dordrecht: Springer Netherlands.

Eswaran, M., & Bahubalendruni, M. R. (2022). Challenges and opportunities on AR/VR technologies for manufacturing systems in the context of industry 4.0: A state of the art review. Journal of Manufacturing Systems, 65, 260-278.

Evans, L. (2018). The re-emergence of virtual reality. Routledge.

Evans-Cowley, J., & Hollander, J. (2010). The new generation of public participation: Internet-based participation tools. Planning Practice & Research, 25(3), 397-408.

Evans, G. W., & Lepore, S. J. (1992). Conceptual and analytic issues in crowding research. Journal of Environmental Psychology, 12(2), 163-173.

Evans, G.W., Lercher, P. and Kofler, W.W., 2002. Crowding and children's mental health: the role of house type. Journal of environmental psychology, 22(3), pp.221-231.

Evans, G. W. (2003). The built environment and mental health. Journal of Urban Health, 80(4), 536-555.

Evolve Lab. (2023). VERAS: AI design engine for Revit. Retrieved April 6, 2023, from https://www.evolvelab.io/veras

Fainstein, S. S. (2014). The just city. International journal of urban Sciences, 18(1), 1-18.

Fan, P., Ouyang, Z., Basnou, C., Pino, J., Park, H., & Chen, J. (2017). Nature-based solutions for urban landscapes under post-industrialization and globalization: Barcelona versus Shanghai. Environmental Research, 156, 272-283.

Fares, F., Taha, D. S., & Sayad, Z. T. E. (2018). Achieving public participation in inaccessible areas using virtual reality a case study of Beit Hanoun–Gaza–Palestine. Alexandria Engineering Journal, 57(3), 1821-1828.

Fazeli, N., Oller, M., Wu, J., Wu, Z., Tenenbaum, J. B., & Rodriguez, A. (2019). See, feel, act: Hierarchical learning for complex manipulation skills with multisensory fusion. Science Robotics, 4(26), eaav3123

Fernández Per, A., Mozas, J., Arpa, J., & Holl, S. (2011). This is Hybrid: an analysis of mixed-use building by a+ t.

Felus, K. (2016). The Secret Life of the Georgian Garden: Beautiful Objects and Agreeable Retreats. Bloomsbury Publishing.

Fischler, R. (1998). The metropolitan dimension of early zoning: Revisiting the 1916 New York City ordinance. Journal of the American Planning Association, 64(2), 170-188.

Fischler, R. (2012). Fifty theses on urban planning and urban planners. Journal of Planning Education and Research, 32(1), 107-114.

Fisher, B. S., & Nasar, J. L. (1992). Fear of crime in relation to three exterior site features: Prospect, refuge, and escape. *Environment and behavior*, *24*(1), 35-65.

Flood, A. (2010). Understanding phenomenology. Nurse researcher, 17(2).

Fonseca, D., Cavalcanti, J., Peña, E., Valls, V., Sanchez-Sepúlveda, M., Moreira, F., ... & Redondo, E. (2021). Mixed assessment of virtual serious games applied in architectural and urban design education. Sensors, 21(9), 3102.

Fonseca, D., Villagrasa, S., Navarro, I., Redondo, E., Valls, F., & Sánchez, A. (2017). Urban gamification in architecture education. In Recent Advances in Information Systems and Technologies: Volume 3 5 (pp. 335-341). Springer International Publishing.

Font, A., Guiseppin, L., Blangiardo, M., Ghersi, V., & Fuller, G. W. (2019). A tale of two cities: is air pollution improving in Paris and London?. Environmental Pollution, 249, 1-12.

Forrest, M., & Konijnendijk, C. (2005). A history of urban forests and trees in Europe. Urban forests and trees, 23-48.

Forsyth, A., 2008. Design and Destinations: Factors Influencing Walking and Total Physical Activity. Urban Studies, 45(9), p. 1973–1996

Francis, J., Giles-Corti, B., Wood, L., & Knuiman, M. (2012). Creating sense of community: The role of public space. Journal of environmental psychology, 32(4), 401-409.

Frantzeskaki, N., Broto, V. C., Coenen, L., & Loorbach, D. (2017). Urban sustainability transitions: The dynamics and opportunities of sustainability transitions in cities. In Urban sustainability transitions (pp. 1-20). Routledge

Fraser, N. (2021). Rethinking the public sphere: A contribution to the critique of actually existing democracy. In Public Space Reader (pp. 34-41). Routledge.

Frith, M., Brennan, E., & House, S. (2007). LONDON’S GREEN BELT.

Gaffikin, F., Mceldowney, M., & Sterrett, K. (2010). Creating shared public space in the contested city: The role of urban design. Journal of Urban Design, 15(4), 493-513.

Galderisi, S., Heinz, A., Kastrup, M., Beezhold, J., & Sartorius, N. (2015). Toward a new definition of mental health. *World psychiatry*, *14*(2), 231.

Galián, L. (2019). Squares, Occupy Movements and the Arab Revolutions. In The Palgrave Handbook of Anarchism (pp. 715-732). Palgrave Macmillan, Cham.

Gallace, A. (2022). Haptic Interaction in Virtual Reality. Handbook of Research on Implementing Digital Reality and Interactive Technologies to Achieve Society 5.0, 1.

Gan, V. J., Lo, I. M., Ma, J., Tse, K. T., Cheng, J. C., & Chan, C. M. (2020). Simulation optimisation towards energy efficient green buildings: Current status and future trends. Journal of Cleaner Production, 254, 120012.

Gandhi, M., & Marr, L. C. (2021). Uniting infectious disease and physical science principles on the importance of face masks for COVID-19. Med, 2(1), 29-32.

Gant, R. L., Robinson, G. M., & Fazal, S. (2011). Land-use change in the 'edgelands': Policies and pressures in London's rural–urban fringe. Land use policy, 28(1), 266-279.

Gao, G., & Li, W. (2022). Architecture of visual design creation system based on 5G virtual reality. International Journal of Communication Systems, 35(5), e4750.

Gehl, J. (1989). A changing street life in a changing society. Places, 6(1).

Gehl, J. (2011). Life between buildings. Island Press.

Gehl, J., Svarre, B. (2013). Public Space, Public Life: an Interaction. In: How To Study Public Life. Island Press, Washington, DC. https://doi.org/10.5822/978-1-61091-525-0_1

Gehl, J., & Svarre, B. (2013). How to study public life (Vol. 2). Washington, DC: Island press.

Gehl, J. (1987). Life between buildings (Vol. 23). New York: Van Nostrand Reinhold.

Geertz, C. (1973). The interpretation of cultures (Vol. 5043). Basic books.

Generalova, E., & Generalov, V. (2020, February). Mixed-use high-rise buildings: a typology of the future. In IOP Conference Series: Materials Science and Engineering (Vol. 753, No. 2, p. 022062). IOP Publishing.

Geng, D., Innes, J., Wu, W., & Wang, G. (2021). Impacts of COVID-19 pandemic on urban park visitation: a global analysis. Journal of forestry research, 32, 553-567.

Gifford, R. (2007). Environmental psychology: Principles and practice (4th ed.). Optimal Books.

Giles-Corti, B., Moudon, A. V., Lowe, M., Cerin, E., Boeing, G., Frumkin, H., ... & Sallis, J. F. (2022). What next? Expanding our view of city planning and global health, and implementing and monitoring evidence-informed policy. The lancet global health, 10(6), e919-e926.

Glassman, M., & Erdem, G. (2014). Participatory action research and its meanings: Vivencia, praxis, conscientization. Adult education quarterly, 64(3), 206-221.

Goffman, E. (2008). Behavior in public places. Simon and Schuster.

Gold, J. R., & Gold, M. (2010). Olympic cities: urban planning, city agendas and the world's games, 1896 to the present.

Gomez-Jacinto, L. and Hombrados-Mendieta, I., 2002. Multiple effects of community and household crowding. Journal of Environmental Psychology, 22(3), pp.233-246.

Gomez-Tone, H. C., Alpaca Chávez, M., Vásquez Samalvides, L., & Martin-Gutierrez, J. (2022). Introducing Immersive Virtual Reality in the Initial Phases of the Design Process—Case Study: Freshmen Designing Ephemeral Architecture. Buildings, 12(5), 518.

Goodman, P. S. (2003). The garden squares of Boston. UPNE.

Goosen, Z., & Cilliers, E. J. (2020). Enhancing social sustainability through the planning of third places: A theory-based framework. Social Indicators Research, 150(3), 835-866.

Götzelmann, T., & Kreimeier, J. (2020, June). Towards the inclusion of wheelchair users in smart city planning through virtual reality simulation. In Proceedings of the 13th ACM International Conference on PErvasive Technologies Related to Assistive Environments (pp. 1-7).

Gould, C. (2022). The Inclusions and Exclusions of British Public Art: Creating Art for the Successful City, or for the Just City?. Études britanniques contemporaines. Revue de la Société d'études anglaises contemporaines, (63).

Goss, R. O. (1990). Economic policies and seaports: are port authorities necessary?. Maritime Policy & Management, 17(4), 257-271.

Greater London Authority. (2011). Managing London's public space. London City Hall. Retrieved July 3, 2023, from: https://www.london.gov.uk/sites/default/files/gla_migrate_files_destination/Public%20space%20June%202011%20Webme.pdf

Greater London Authority. (2019). About Good Growth by Design. Retrieved July 8, 2021 from: https://www.london.gov.uk/what-wedo/regeneration/advice-and-guidance/about-good-growth-design

Greengard, S. (2019). Virtual reality. Mit Press.

Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. Handbook of qualitative research, 2(163-194), 105.

Guetterman, T. C., Fetters, M. D., & Creswell, J. W. (2015). Integrating quantitative and qualitative results in health science mixed methods research through joint displays. The Annals of Family Medicine, 13(6), 554-561.

Gunn, S. C. (2007). Green belts: A review of the regions' responses to a changing housing Agenda. Journal of Environmental Planning and Management, 50(5), 595-616.

Gupta, N. (2020). <? covid19?> Singing Away the Social Distancing Blues: Art Therapy in a Time of Coronavirus. Journal of Humanistic Psychology, 60(5), 593-603.

Habermas, J., Lennox, S., & Lennox, F. (1974). The public sphere: An encyclopedia article (1964). New German Critique, (3), 49-55.

Habermas, J. (2010). The public sphere: an encyclopedia article (1964). The idea of the public sphere: A reader, 114.

Hadi, Y., Heath, T., & Oldfield, P. (2018). Gardens in the sky: Emotional experiences in the communal spaces at height in the Pinnacle@ Duxton, Singapore. Emotion, Space and Society, 28, 104-11

Hadi, Y., Heath, T., & Oldfield, P. (2014, September). Vertical Public Realms: Creating Urban Spaces in the Sky. In Proceedings of the CTBUH 2014 Shanghai Conference Proceedings, Shanghai, China (pp. 16-19).

Hagan, S.,2019, Designing London's Public Spaces: Post-war and now, Lund Humphries, London

Hakak, S., Noor, N. F. M., Ayub, M. N., Affal, H., Hussin, N., & Imran, M. (2019). Cloud-assisted gamification for education and learning–Recent advances and challenges. Computers & Electrical Engineering, 74, 22-34.

Hamdi, N., & Goethert, R. (1997). Action planning for cities. John Wiley.

Hammond, M., & Wellington, J. (2020). Research methods: The key concepts. Routledge.

Hamari, J., Koivisto, J., & Sarsa, H. (2014, January). Does gamification work?--a literature review of empirical studies on gamification. In 2014 47th Hawaii international conference on system sciences (pp. 3025-3034). Ieee.

Han, A. T., & Go, M. H. (2019). Explaining the national variation of land use: A cross-national analysis of greenbelt policy in five countries. Land Use Policy, 81, 644-656.

Hanson, K., & Shelton, B. E. (2008). Design and development of virtual reality: analysis of challenges faced by educators. Journal of Educational Technology & Society, 11(1), 118-131.

Hanzl, M., & Ledwon, S. (2017). Analyses of human behaviour in public spaces. ISOCARP, Portland, Oregon, USA.

Harman, J., Brown, R., & Johnson, D. (2017). Improved memory elicitation in virtual reality: new experimental results and insights. In Human-Computer Interaction-INTERACT 2017: 16th IFIP TC 13 International Conference, Mumbai, India, September 25-29, 2017, Proceedings, Part II 16 (pp. 128-146). Springer International Publishing.

Hartig, T., Mitchell, R., De Vries, S., & Frumkin, H. (2014). Nature and health. Annual Review of Public Health, 35, 207-228. https://doi.org/10.1146/annurev-publhealth-032013-182443

Harvey, D. (2012). Rebel cities: From the right to the city to the urban revolution. Verso books.

Hayllar, B., & Griffin, T. (2005). The precinct experience: a phenomenological approach. Tourism Management, 26(4), 517-528.

Healey, P. (1995). The institutional challenge for sustainable urban regeneration. Cities, 12(4), 221-230.

Heilig, M. L. (1962). Sensorama simulator. US PAT. 3,050,870.

Ho, D. C., Lai, L. W., & Wang, A. (2021). The effects of 'publicness' and quality of publicly accessible open space upon user satisfaction. Environment and Planning B: Urban Analytics and City Science, 48(4), 861-879.

Holl, S. (2014). Hybrid buildings. Oz, 36(1), 12.

Holmström, J., Ketokivi, M., & Hameri, A. P. (2009). Bridging practice and theory: A design science approach. Decision sciences, 40(1), 65-87.

Honey-Rosés, J., Anguelovski, I., Chireh, V. K., Daher, C., Konijnendijk van den Bosch, C., Litt, J. S., ... & Nieuwenhuijsen, M. J. (2021). The impact of COVID-19 on public space: an early review of the emerging questions–design, perceptions and inequities. Cities & health, 5(sup1), S263-S279.

Hooks, K., Ferguson, W., Morillo, P., & Cruz-Neira, C. (2020). Evaluating the user experience of omnidirectional VR walking simulators. Entertainment Computing, 34, 100352.

Hou, J., & Rios, M. (2003). Community-driven place making: the social practice of participatory design in the making of Union Point Park. Journal of Architectural Education, 57(1), 19-27.

Howard, Z., & Somerville, M. M. (2014). A comparative study of two design charrettes: implications for codesign and participatory action research. CoDesign, 10(1), 46-62.

Hsieh, H. F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. Qualitative health research, 15(9), 1277-1288.

Hsu, T. W., Tsai, M. H., Babu, S. V., Hsu, P. H., Chang, H. M., Lin, W. C., & Chuang, J. H. (2020, March). Design and initial evaluation of a VR based immersive and interactive architectural design discussion system. In 2020 IEEE Conference on Virtual Reality and 3D User Interfaces (VR) (pp. 363-371). IEEE.

Hubbard, P. (2020). Legal pluralism at the beach: Public access, land use, and the struggle for the “coastal commons”. Area, 52(2), 420-428.

Huang, J., Chen, Z., Ceylan, D., & Jin, H. (2017, March). 6-DOF VR videos with a single 360-camera. In 2017 IEEE Virtual Reality (VR) (pp. 37-44). IEEE.

Huang, T. S., & Franck, K. A. (2018). Let’s meet at Citicorp: can privately owned public spaces be inclusive?. Journal of Urban Design, 23(4), 499-517.

Huang, Y., Shakya, S., & Odeleye, T. (2019). Comparing the functionality between virtual reality and mixed reality for architecture and construction uses. Journal of Civil Engineering and Architecture, 13(1), 409-414.

Huang, Z., Lu, Y., Wong, N. H., & Poh, C. H. (2019). The true cost of “greening” a building: Life cycle cost analysis of vertical greenery systems (VGS) in tropical climate. Journal of Cleaner Production, 228, 437-454.

Hume, D. (2007). An enquiry concerning human understanding and other writings.

Humphreys, L. (2010). Mobile social networks and urban public space. New Media & Society, 12(5), 763-778.

Huusko, M., Wu, Y., & Roto, V. (2018, December). Structuring and engaging: the roles of design fictions in a co-design workshop. In Proceedings of the 30th Australian Conference on Computer-Human Interaction (pp. 234-241).

Huybrechts, L., Benesch, H., & Geib, J. (2017). Institutioning: Participatory design, co-design and the public realm. CoDesign, 13(3), 148-159.

Ijeh, I. (2020). Designing London: Understanding the Character of the City. United Kingdom: Lund Humphries Publishers, Limited.

Ilgin, H. E. (2021). A search for A New tall building typology: structural hybrids. Proceedings of the LivenARCH.

Imrie, R. (2012). Universalism, universal design and equitable access to the built environment. Disability and rehabilitation, 34(10), 873-882.

Ismail, W. A. W., & Said, I. (2015). Integrating the community in urban design and planning of public spaces: a review in Malaysian cities. Procedia-Social and Behavioral Sciences, 168, 357-364.

Iwarsson, S., & Ståhl, A. (2003). Accessibility, usability and universal design—positioning and definition of concepts describing person-environment relationships. Disability and rehabilitation, 25(2), 57-66.

IVESON, K., 2007. Publics and the city. Oxford, Blackwell.

Iveson, K. (2013). Cities within the city: Do-it-yourself urbanism and the right to the city. International journal of urban and regional research, 37(3), 941-956.

Jacobs, J., 2016. The death and life of great American cities. New York: Vintage.

Jacques, D. (2017). Gardens of Court and Country: English Design, 1630-1730. Yale University Press.

Jackson, S. B., Stevenson, K. T., Larson, L. R., Peterson, M. N., & Seekamp, E. (2021). Outdoor activity participation improves adolescents' mental health and well-being during the COVID-19 pandemic. International Journal of Environmental Research and Public Health, 18(5), 2506.

Jalal, A., Mahmood, M., & Hasan, A. S. (2019, January). Multi-features descriptors for human activity tracking and recognition in Indoor-outdoor environments. In 2019 16th International Bhurban Conference on Applied Sciences and Technology (IBCAST) (pp. 371-376). IEEE.

Jalo, H., Pirkkalainen, H., Torro, O., Lounakoski, M., & Puhto, J. (2020, June). Enabling factors of social virtual reality diffusion in organizations. Association for Information Systems.

Jamei, E., Mortimer, M., Seyedmahmoudian, M., Horan, B., & Stojcevski, A. (2017). Investigating the role of virtual reality in planning for sustainable smart cities. Sustainability, 9(11), 2006.

James, E. A., Milenkiewicz, M. T., & Bucknam, A. (2007). Participatory action research for educational leadership: Using data-driven decision making to improve schools. Sage Publications.

Jenks, M., Burton, E., & Williams, K. (1996). Compact cities and sustainability: an introduction. The Compact City: a sustainable urban form, 11-12.

Jenkins, D. (1993). Unité d'Habitation Marseilles: Le Corbusier. (No Title).

Jens, K., & Gregg, J. S. (2021). The impact on human behaviour in shared building spaces as a result of COVID-19 restrictions. Building Research & Information, 49(8), 827-841.

Jha, A. K., Ghimire, A., Thapa, S., Jha, A. M., & Raj, R. (2021, January). A review of AI for urban planning: Towards building sustainable smart cities. In 2021 6th International Conference on Inventive Computation Technologies (ICICT) (pp. 937-944). IEEE.

Jia, M., Komeily, A., Wang, Y., & Srinivasan, R. S. (2019). Adopting Internet of Things for the development of smart buildings: A review of enabling technologies and applications. Automation in Construction, 101, 111-126

Jim, C. Y., & Chen, W. Y. (2006). Impacts of urban environmental elements on residential housing prices in Guangzhou (China). Landscape and Urban Planning, 78(4), 422-434.

Johansson, R. (2007). On case study methodology. Open house international, 32(3), 48-54.

Johnson, B. (2009). A Manifesto for Public Space: London's Great Outdoors. Statement of principles and initiatives to revitalize public spaces, Mayor of London Retrieved June 10, 2020, from https://www.london.gov.uk/sites/default/files/londons_great_outdoors_-_mayors_manifesto.pdf

Johnson-Glenberg, M. C. (2018). Immersive VR and education: Embodied design principles that include gesture and hand controls. Frontiers in Robotics and AI, 81.

Jones, P. (2018). Contexts of co-creation: Designing with system stakeholders. Systemic design: Theory, methods, and practice, 3-52.

Jones, S., & Dawkins, S. (2018). The sensorama revisited: evaluating the application of multi-sensory input on the sense of presence in 360-degree immersive film in virtual reality. Augmented Reality and Virtual Reality: Empowering Human, Place and Business, 183-197.

Jones, W. (2017). Sky garden. Green: sustainable architecture and landscape design, (53), 64-69.

Juris, J. S. (2016). Reflections on# Occupy Everywhere: Social media, public space, and emerging logics of aggregation. In Youth, space and time (pp. 385-414). Brill.

Kalantari, S., & Neo, J. R. J. (2020). Virtual environments for design research: Lessons learned from use of fully immersive virtual reality in interior design research. Journal of Interior Design, 45(3), 27-42.

Kalantari, S., & Shepley, M. (2021). Psychological and social impacts of high-rise buildings: A review of the post-occupancy evaluation literature. Housing studies, 36(8), 1147-1176.

Kalawsky, R. S. (2000, March). The validity of presence as a reliable human performance metric in immersive environments. In 3rd International Workshop on Presence (pp. 1-16).

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. Journal of environmental psychology, 15(3), 169-182.

Kaplan, R., Kaplan, S., & Brown, T. (1989). Environmental preference: A comparison of four domains of predictors. Environment and behavior, 21(5), 509-530.

Katoppo, M. L., & Sudradjat, I. (2015). Combining Participatory Action Research (PAR) and Design Thinking (DT) as an alternative research method in architecture. Procedia-Social and Behavioral Sciences, 184, 118-125.

Kavouras, I., Sardis, E., Protopapadakis, E., Rallis, I., Doulamis, A., & Doulamis, N. (2023). A Low-Cost Gamified Urban Planning Methodology Enhanced with Co-Creation and Participatory Approaches. Sustainability, 15(3), 2297.

Kaya, N., & Erkip, F. (2001). Satisfaction in a dormitory building: The effects of floor height on the perception of room size and crowding. Environment and Behavior, 33(1), 35-53.

Keane, J. (2018). Structural transformations of the public sphere. In The Media, Journalism and Democracy (pp. 53-74). Routledge.

Keller, L. (2009). Triumph of order: Democracy & public space in New York and London. Columbia University Press.

Kellert, S. R., Heerwagen, J., & Mador, M. (2011). Biophilic design: the theory, science and practice of bringing buildings to life. John Wiley & Sons.

Kellert, S. R., & Wilson, E. O. (Eds.). (1995). The biophilia hypothesis. Island press.

Kenawy, I., & Ehab, A. (2015). Community participation as a gate to new Egyptian society. In PLEA 2015 Conference Proceedings. PLEA 2015

Kersten, T. P., Tschirschwitz, F., Deggim, S., & Lindstaedt, M. (2018). Virtual reality for cultural heritage monuments–from 3D data recording to immersive visualisation. In Digital Heritage. Progress in Cultural Heritage: Documentation, Preservation, and Protection: 7th International Conference, EuroMed 2018, Nicosia, Cyprus, October 29–November 3, 2018, Proceedings, Part II 7 (pp. 74-83). Springer International Publishing.

Keshavarz, B., & Golding, J. F. (2022). Motion sickness: current concepts and management. Current opinion in neurology, 35(1), 107-112.

Keung, C. C. W., Kim, J. I., & Ong, Q. M. (2021). Developing a BIM-based MUVR treadmill system for architectural design review and collaboration. Applied Sciences, 11(15), 6881.

Khan, A., Sepasgozar, S., Liu, T., & Yu, R. (2021). Integration of BIM and immersive technologies for AEC: A scientometric-SWOT analysis and critical content review. Buildings, 11(3), 126

Khan, S., 2018. London Housing Strategy, London: Greater London Authority.

Khan, S., 2020. Public London Charter, London: Greater London Authority.

Khan, A., Sepasgozar, S., Liu, T., & Yu, R. (2021). Integration of BIM and immersive technologies for AEC: A scientometric-SWOT analysis and critical content review. Buildings, 11(3), 126.

Kharvari, F., & Kaiser, L. E. (2022). Impact of extended reality on architectural education and the design process. Automation in Construction, 141, 104393.

Khundam, C., Vorachart, V., Preeyawongsakul, P., Hosap, W., & Noël, F. (2021, September). A comparative study of interaction time and usability of using controllers and hand tracking in virtual reality training. In Informatics (Vol. 8, No. 3, p. 60). MDPI.

Kim, S., Kim, J., & Kim, B. (2020). Immersive virtual reality-aided conjoint analysis of urban square preference by living environment. Sustainability, 12(16), 6440.

Kim, S., Park, H., & Choo, S. (2021). Effects of Changes to Architectural Elements on Human Relaxation-Arousal Responses: Based on VR and EEG. International journal of environmental research and public health, 18(8), 4305.

Kingwell, M. (2006). Nearest Thing to Heaven: The Empire State Building and American Dreams. Yale University Press.

Kirwan, C. G., & Zhiyong, F. (2020). Smart cities and artificial intelligence: convergent systems for planning, design, and operations. Elsevier.

Kitchin, R., Young, G. W., & Dawkins, O. (2021). Planning and 3D spatial media: Progress, prospects, and the knowledge and experiences of local government planners in Ireland. Planning theory & practice, 22(3), 349-367.

Kitson, A., Prpa, M., & Riecke, B. E. (2018). Immersive interactive technologies for positive change: a scoping review and design considerations. Frontiers in psychology, 9, 1354.

Knudsen, L. V., Laplante-Levesque, A., Jones, L., Preminger, J. E., Nielsen, C., Lunner, T., ... & Kramer, S. E. (2012). Conducting qualitative research in audiology: A tutorial. International journal of audiology, 51(2), 83-92.

Koohang, A., Nord, J. H., Ooi, K. B., Tan, G. W. H., Al-Emran, M., Aw, E. C. X., ... & Wong, L. W. (2023). Shaping the metaverse into reality: a holistic multidisciplinary understanding of opportunities, challenges, and avenues for future investigation. Journal of Computer Information Systems, 63(3), 735-765.

Kolarevic, B. (2003). Digital production. Architecture in the digital age: design and manufacturing, 38, 63.

Kopeć, W., Skorupska, K., Jaskulska, A., Abramczuk, K., Nielek, R., & Wierzbicki, A. (2017, August). Livinglab pjait: Towards better urban participation of seniors. In Proceedings of the International Conference on Web Intelligence (pp. 1085-1092).

Koskela, H. (2002). Video surveillance, gender, and the safety of public urban space:" Peeping Tom" goes high tech?. Urban geography, 23(3), 257-278.

Kozlovska, M., Klosova, D., & Strukova, Z. (2021). Impact of industry 4.0 platform on the formation of construction 4.0 concept: a literature review. Sustainability, 13(5), 2683.

Krasilnikova, E., & Klimov, D. (2016). The main design principles of hybrid spaces in terms of the urban planning regeneration. Вестник Российского университета дружбы народов. Серия: Агрономия и животноводство, (4), 63-74.

Krueger, R. A. (2014). Focus groups: A practical guide for applied research. Sage publications.

Kufner, J. (2011). Tall building policy making and implementation in central London: Visual impacts on regionally protected views from 2000 to 2008 (Doctoral dissertation, London School of Economics and Political Science).

Kusumaningdyah, N. H., & Purnamasari, L. S. (2018). The techniques of participatory design for inclusive public space provision in kampung kota of Surakarta. In SHS Web of Conferences (Vol. 41, p. 07007). EDP Sciences.

Lai, L. W., Chau, K. W., & Cheung, P. A. C. (2018). Urban renewal and redevelopment: Social justice and property rights with reference to Hong Kong's constitutional capitalism. Cities, 74, 240-248.

Lang, J. (2020). The Routledge companion to twentieth and early twenty-first century urban design: A history of shifting manifestoes, paradigms, generic solutions, and specific designs. Routledge.

Langdridge, D. (2007). Phenomenological psychology: Theory, research and method. Pearson education.

Larwood, J. (1881). The story of the London parks. Chatto and Windus.

Lavdas, A. A., Mehaffy, M. W., & Salingaros, N. A. (2023). AI, the beauty of places, and the metaverse: beyond "geometrical fundamentalism". Architectural Intelligence, 2(1), 8.

Lawrence, H. W. (1993). The greening of the squares of London: transformation of urban landscapes and ideals. Annals of the Association of American Geographers, 83(1), 90-118.

Lawson, B., 2010. The social and psychological issues of high-density city space. Designing high-density cities for social and environmental sustainability, pp.285-292.

Leclercq, E., & Pojani, D. (2021). Public space privatisation: are users concerned?. Journal of Urbanism: International Research on Placemaking and Urban Sustainability, 1-18.

Lee, D., & Park, B. (2018). Effects of elevated public skygarden on employees' psychological restoration-A case study of Seoullo 7017; 12(2), 51-60.

Lee, G. K., & Chan, E. H. (2008). Factors affecting urban renewal in high-density city: Case study of Hong Kong. Journal of Urban Planning and Development, 134(3), 140-148.

Lee, R., & Tucker, K. (2010). "It's My Park": Reinterpreting the History of Birkenhead Park within the Context of an Education Outreach Project. The Public Historian, 32(3), 64-97.

Lees, L. (2014). Gentrification in the global south?. In The Routledge handbook on cities of the global south (pp. 528-543). Routledge.

Lee, L. H., Braud, T., Zhou, P., Wang, L., Xu, D., Lin, Z., ... & Hui, P. (2021). All one needs to know about metaverse: A complete survey on technological singularity, virtual ecosystem, and research agenda. arXiv preprint arXiv:2110.05352.

Lee, R., & Tucker, K. (2010). "It's My Park": Reinterpreting the History of Birkenhead Park within the Context of an Education Outreach Project. The Public Historian, 32(3), 64-97.

Leeson, G. W. (2018). The growth, ageing and urbanisation of our world. Journal of Population Ageing, 11, 107-115.

Lehmann, S. (2016). Sustainable urbanism: towards a framework for quality and optimal density?. Future cities and environment, 2, 1-13.

Leng, J., Sha, W., Wang, B., Zheng, P., Zhuang, C., Liu, Q., ... & Wang, L. (2022). Industry 5.0: Prospect and retrospect. Journal of Manufacturing Systems, 65, 279-295.

Levenda, A. M., Keough, N., Rock, M., & Miller, B. (2020). Rethinking public participation in the smart city. The Canadian geographer/Le géographe canadien, 64(3), 344-358.

Li, J., George, C., Ngao, A., Holländer, K., Mayer, S., & Butz, A. (2021). Rear-seat productivity in virtual reality: Investigating vr interaction in the confined space of a car. Multimodal Technologies and Interaction, 5(4), 15.

Li, Y., Du, H., & Sezer, C. (2022). Sky Gardens, Public Spaces and Urban Sustainability in Dense Cities: Shenzhen, Hong Kong and Singapore. Sustainability, 14(16), 9824.

Lin, Z. (2018). Vertical urbanism: Re-conceptualizing the compact city. Vertical Urbanism, 3-18.

Lincoln, Y. S., Guba, E. G., & Pilotta, J. J. (1985). Naturalistic inquiry. Beverly Hills. CA: Sage Publications. Lee, WS (2001). Parents divorce and their duty to support the expense of bringing up their child. Asian Women, 13(1), 85-105.

Lindner, C., & Rosa, B. (Eds.). (2017). Deconstructing the high line: postindustrial Urbanism and the rise of the elevated park. Rutgers University Press.

Lindgren, R., & Johnson-Glenberg, M. (2013). Emboldened by embodiment: Six precepts for research on embodied learning and mixed reality. Educational researcher, 42(8), 445-452.

Littke, H., Locke, R., & Haas, T. (2016). Taking the High Line: elevated parks, transforming neighbourhoods, and the ever-changing relationship between the urban and nature. Journal of Urbanism: International Research on Placemaking and Urban Sustainability, 9(4), 353-371.

Liu, R., Wang, L., Lei, J., Wang, Q., & Ren, Y. (2020). Effects of an immersive virtual reality-based classroom on students' learning performance in science lessons. British Journal of Educational Technology, 51(6), 2034-2049.

Liu, S., Xie, B., Tivendale, L., & Liu, C. (2015). Critical barriers to BIM implementation in the AEC industry.

Liu, Z., Lu, Y., & Peh, L. C. (2019). A review and scientometric analysis of global building information modeling (BIM) research in the architecture, engineering and construction (AEC) industry. Buildings, 9(10), 210.

Loder, A. (2014). 'There's a meadow outside my workplace': A phenomenological exploration of aesthetics and green roofs in Chicago and Toronto. Landscape and urban planning, 126, 94-106.

Lofland, L. H. (2017). The public realm: Exploring the city's quintessential social territory. Routledge.

Loftman, P., & Nevin, B. (1995). Prestige projects and urban regeneration in the 1980s and 1990s: A review of benefits and limitations. Planning Practice & Research, 10(3-4), 299-316.

London Assembly Planning and Housing Committee, 2011. Public life in private hands (Managing London's public space), London: Greater London Authority.

London First, & Quod SERC at LSE. (2015). The Green Belt: A place for Londoners? London First. http://eprints.lse.ac.uk/87694/

London School of Economics, 2016. A 21st Century Metropolitan Green Belt, London: The London School of Economics and Political Science.

Longstaffe-Gowan, T. (2012). The London Square: Gardens in the midst of town. (No Title).

Low, S. M. (2006). The erosion of public space and the public realm: paranoia, surveillance and privatization in New York City. City & Society, 18(1), 43-49.

Low, S., & Iveson, K. (2016). Propositions for more just urban public spaces. City, 20(1), 10-31.

Lu, Q., Chang, N. B., Joyce, J., Chen, A. S., Savic, D. A., Djordjevic, S., & Fu, G. (2018). Exploring the potential climate change impact on urban growth in London by a cellular automata-based Markov chain model. Computers, Environment and Urban Systems, 68, 121-132.

Luck, R. (2003). Dialogue in participatory design. Design studies, 24(6), 523-535.

Lubin, J. (2016). Humanizing the megascale. CTBUH Journal, (1), 12-18.

Luo, S., Xie, J., & Furuya, K. (2021). "We need such a space": residents' motives for visiting urban green spaces during the COVID-19 pandemic. Sustainability, 13(12), 6806.

Lynch, K. (1964). The image of the city. MIT press.

Mace, A., Blanc, F., Gordon, I. R., & Scanlon, K. (2016). A 21st century metropolitan green belt.

Mack, K., & Ruud, R. (2019). Unreal Engine 4 Virtual Reality Projects: Build Immersive, Real-world VR Applications Using UE4, C++, and Unreal Blueprints. Packt Publishing Ltd.

Madanipour, A. (1999). Why are the design and development of public spaces significant for cities?. Environment and planning B: Planning and Design, 26(6), 879-891.

Madanipour, A., 2003. Public and private spaces of the city. London: Routledge.

Madanipour, A. (2010). Marginal public spaces in European cities. In Whose Public Space? (pp. 111-130). Routledge.

Madanipour, A. (2019). Rethinking public space: between rhetoric and reality. Urban Design International, 24(1), 38-46.

Magliocco, A. (2018). Vertical greening systems: Social and aesthetic aspects. In Nature based strategies for urban and Building Sustainability (pp. 263-271). Butterworth-Heinemann.

Mahtab-uz-Zaman, Q. M., Lau, S. S., & Mei, S. H. (2000). The compact city of Hong Kong: a sustainable model for Asia?. The compact cities: Sustainable urban form for developing countries, 255-268.

Malchow, H. L. (1985). Public gardens and social action in late Victorian London. Victorian Studies, 29(1), 97-124.

Manso, M., Sousa, V., Silva, C. M., & Cruz, C. O. (2021). The role of green roofs in post COVID-19 confinement: An analysis of willingness to pay. Journal of Building Engineering, 44, 103388.

Manis, K. T., & Choi, D. (2019). The virtual reality hardware acceptance model (VR-HAM): Extending and individuating the technology acceptance model (TAM) for virtual reality hardware. Journal of Business Research, 100, 503-513.

Manzini, E., & Rizzo, F. (2011). Small projects/large changes: Participatory design as an open participated process. CoDesign, 7(3-4), 199-215.

Marcus, C. C., & Francis, C. (Eds.). (1997). People places: design guidlines for urban open space. John Wiley & Sons.

March, L., & Lehrer, U. (2022). Common Areas, Common Causes: Public Space in High-Rise Buildings During Covid-19

March, L. and Martin, L. eds., 1972. Urban space and structures. Cambridge: University Press.

Markham, L. (2008). The Protection of Views of St Paul's Cathedral and its Influence on the London Landscape. the london journal, 33(3), 271-287.

Marom, N. (2013). Activising space: The spatial politics of the 2011 protest movement in Israel. Urban Studies, 50(13), 2826-2841.

Martínez-Navarro, J., Bigné, E., Guixeres, J., Alcañiz, M., & Torrecilla, C. (2019). The influence of virtual reality in e-commerce. Journal of Business Research, 100, 475-482.

Morawska, L., Allen, J., Bahnfleth, W., Bluyssen, P. M., Boerstra, A., Buonanno, G., ... & Yao, M. (2021). A paradigm shift to combat indoor respiratory infection. Science, 372(6543), 689-691.

Masnavi, M. R., Gharai, F., & Hajibandeh, M. (2019). Exploring urban resilience thinking for its application in urban planning: A review of literature. International journal of environmental science and technology, 16, 567-582.

Mason, R.B., 1995. Muqarnas: Annual on Islamic Art and Architecture, Leiden: Brill Academic Publisher

Mattern, S. (2016). Instrumental city: The view from Hudson Yards, circa 2019. Places Journal.

Matua, G. A., & Van Der Wal, D. M. (2015). Differentiating between descriptive and interpretive phenomenological research approaches. Nurse researcher, 22(6).

Mayekar, H. (2017). Under One Roof: Hybrid Architecture for Auckland a Master’s Thesis. Unitec Institute of Technology, New Zealand retrieved from. https://hdl. ha ndle. net/10652/4384.

McVeigh-Schultz, J., Kolesnichenko, A., & Isbister, K. (2019, May). Shaping pro-social interaction in VR: an emerging design framework. In Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (pp. 1-12).

Mealy, P. (2018). Virtual & augmented reality for dummies. John Wiley & Sons.

Mechanic, D. (1999). Mental health and mental illness: definitions and perspectives.

Meenar, M., & Kitson, J. (2020). Using multi-sensory and multi-dimensional immersive virtual reality in participatory planning. Urban Science, 4(3), 34.

Megahed, N. A., & Ghoneim, E. M. (2020). Antivirus-built environment: Lessons learned from Covid-19 pandemic. Sustainable cities and society, 61, 102350.

Mehta, V. (2014). Evaluating public space. Journal of Urban design, 19(1), 53-88.

Mell, I., & Whitten, M. (2021). Access to nature in a post Covid-19 world: Opportunities for green infrastructure financing, distribution and equitability in urban planning. International Journal of Environmental Research and Public Health, 18(4), 1527.

Mertens, D. M. (2007). Transformative paradigm: Mixed methods and social justice. Journal of mixed methods research, 1(3), 212-225.

Mertens, D. M. (2010). Transformative mixed methods research. Qualitative inquiry, 16(6), 469-474.

Millais, M. (2015). A critical appraisal of the design, construction and influence of the Unité d'Habitation, Marseilles, France. Journal of Architecture and Urbanism, 39(2), 103-115.

Milgram, P., & Kishino, F. (1994). A taxonomy of mixed reality visual displays. IEICE TRANSACTIONS on Information and Systems, 77(12), 1321-1329.

Miller, K. F. (2007). Designs on the public: The private lives of New York's public spaces. U of Minnesota Press.

Miller, R. M., Chan, C. D., & Farmer, L. B. (2018). Interpretative phenomenological analysis: A contemporary qualitative approach. Counselor Education and Supervision, 57(4), 240-254. Miller, R.

Mills, S., Brahney, A., & Mackay, S. (2020). New Solutions for the New Normal. CTBUH Journal, (4).

Minton, A. 2006. What Kind of World are we Building? The Privatisation of Public Space, London: RICS, The Royal Institution of Chartered Surveyors.

Minton, A. (2012). Ground Control: Fear and happiness in the twenty-first-century city. Penguin UK.

Mitrasinovic, M. (2006). Total landscape, theme parks, public space. Ashgate Publishing, Ltd..

Monahan, T., McArdle, G., & Bertolotto, M. (2008). Virtual reality for collaborative e-learning. Computers & Education, 50(4), 1339-1353.

Moore, G. M. (2021). Connectivity of public open space: its meaning for different functions. Journal of Urban Design, 26(3), 279-295.

Morakinyo, T. E., Lai, A., Lau, K. K. L., & Ng, E. (2019). Thermal benefits of vertical greening in a high-density city: Case study of Hong Kong. Urban Forestry & Urban Greening, 37, 42-55.

Morato, L. C. (2022). Opportunities and Challenges of Municipal Planning in Shaping Vertical Neighbourhoods in Greater London. Urban Planning, 7(4), 267-283.

Morgan, D. L. (2014). Pragmatism as a paradigm for social research. Qualitative inquiry, 20(8), 1045-1053.

Morse, C. (2021). Gaming Engines: Unity, Unreal, and Interactive 3D Spaces.

Mouratidis, K. (2019). Compact city, urban sprawl, and subjective well-being. Cities, 92, 261-272.

Mouratidis, K. (2021). Urban planning and quality of life: A review of pathways linking the built environment to subjective well-being. Cities, 115, 103229.

Mouratidis, K., & Hassan, R. (2020). Contemporary versus traditional styles in architecture and public space: A virtual reality study with 360-degree videos. Cities, 97, 102499.

Moreham, N. A. (2006). Privacy in public places. The Cambridge Law Journal, 65(3), 606-635.

Moreno, C., Allam, Z., Chabaud, D., Gall, C., & Pratlong, F. (2021). Introducing the “15-Minute City”: Sustainability, resilience and place identity in future post-pandemic cities. Smart Cities, 4(1), 93-111.

Moroni, S. (2016). Urban density after Jane Jacobs: the crucial role of diversity and emergence. City, Territory and Architecture, 3, 1-8.

Mualam, N., Salinger, E., & Max, D. (2019). Increasing the urban mix through vertical allocations: Public floorspace in mixed use development. Cities, 87, 131-141

Münster, S., Georgi, C., Heijne, K., Klamert, K., Noennig, J. R., Pump, M., ... & van der Meer, H. (2017). How to involve inhabitants in urban design planning by using digital tools? An overview on a state of the art, key challenges and promising approaches. Procedia Computer Science, 112, 2391-2405.

Munthe-Kaas, P. (2015). Agonism and co-design of urban spaces. Urban Research & Practice, 8(2), 218-237.

Nabatchi, T., Ertinger, E., & Leighninger, M. (2015). The future of public participation: Better design, better laws, better systems. Conflict Resolution Quarterly, 33(S1), S35-S44.

Naldi, P. (2019). Creating London's Image. In Fragmentation of the Photographic Image in the Digital Age (pp. 57-72). Routledge.

Nanz, P., & Steffek, J. (2004). Global governance, participation and the public sphere. Government and opposition, 39(2), 314-335.

Nee, A. Y., Ong, S. K., Chryssolouris, G., & Mourtzis, D. (2012). Augmented reality applications in design and manufacturing. CIRP annals, 61(2), 657-679.

Németh, J. (2009). Defining a public: The management of privately owned public space. Urban studies, 46(11), 2463-2490.

Németh, J., & Schmidt, S. (2011). The privatization of public space: modeling and measuring publicness. Environment and Planning B: Planning and Design, 38(1), 5-23.

New London Architecture, 2008. DES RES: LONDON'S HOUSING CHALLENGE, London: New London Architecture.

New London Architecture, 2015. Public London: NLA Insight Study, London: The Building Center: New London Architecture.

New London Architecture, 2016. Borough Strategies, London: New London Architecture.

New London Architecture 2019. London Tall Buildings Survey 2019, London: The Building Centre, New London Architecture.

New London Architecture, 2020. The London Boroughs, London: New London Architecture.

Newman, P. (2014). Biophilic urbanism: a case study on Singapore. Australian planner, 51(1), 47-65.

Newman, P. G., & Kenworthy, J. R. (1989). Cities and automobile dependence: An international sourcebook.

Newman, P., & Kenworthy, J. (1999). Sustainability and cities: overcoming automobile dependence. Island press.

Newman, P., & Kenworthy, J. (2007). Sustainable urban form: Transport infrastructure and transport policies. In Threats from car traffic to the quality of urban life (pp. 293-311). Emerald Group Publishing Limited.

Ng, C. F. (2017). Living and working in tall buildings: satisfaction and perceived benefits and concerns of occupants. Frontiers in built environment, 3, 70.

Nilsson, N. C., Serafin, S., Steinicke, F., & Nordahl, R. (2018). Natural walking in virtual reality: A review. Computers in Entertainment (CIE), 16(2), 1-22.

Noghabaei, M., Heydarian, A., Balali, V., & Han, K. (2020). Trend analysis on adoption of virtual and augmented reality in the architecture, engineering, and construction industry. Data, 5(1), 26.

Nordh, H., & Østby, K. (2013). Pocket parks for people–A study of park design and use. Urban forestry & urban gresening, 12(1), 12-17.

North, M. M., & North, S. M. (2016). A comparative study of sense of presence of traditional virtual reality and immersive environments. Australasian Journal of Information Systems, 20.

Nutsford, D., Pearson, A. L., & Kingham, S. (2013). An ecological study investigating the association between access to urban green space and mental health. Public health, 127(11), 1005-1011.

Office for National Statistics, 2021. Coronavirus and depression in adults, Great Britain: January to March 2021. [Online]
Available at:
https://www.ons.gov.uk/peoplepopulationandcommunity/wellbeing/articles/coronavirusanddepressioninadultsgreatbritain/januarytomarch2021
[Accessed 18th September 2021].

Oldenburg, R., 1991. The Great Good Place, New York: Paragon House.

Oldenburg, R. (1999). The great good place: Cafes, coffee shops, bookstores, bars, hair salons, and other hangouts at the heart of a community. Da Capo Press.

Oldenburg, R. (2002). Celebrating the Third Place: Inspiring stories about the "great good places" at the heart of our communities. Marlowe and Company.

Oldenburg, R. (2013). The problem of place in America. In The urban design reader (pp. 305-315). Routledge.

Oldfield, P. (2019). The sustainable tall building: a design primer. Routledge.

Oldfield, P., Trabucco, D., & Wood, A. (2009). Five energy generations of tall buildings: an historical analysis of energy consumption in high-rise buildings. The Journal of Architecture, 14(5), 591-613.

Osmundson, T. (1999). Roof Gardens: History Design And Construction. WW Norton & Company.

Ozer, E. J., Ritterman, M. L., & Wanis, M. G. (2010). Participatory action research (PAR) in middle school: Opportunities, constraints, and key processes. American journal of community psychology, 46, 152-166.

Özerol, G., & Arslan Selçuk, S. (2023). Machine learning in the discipline of architecture: A review on the research trends between 2014 and 2020. International Journal of Architectural Computing, 21(1), 23-41.

Padilla-Díaz, M. (2015). Phenomenology in educational qualitative research: Philosophy as science or philosophical science. International journal of educational excellence, 1(2), 101-110.

Pan, Y., & Zhang, L. (2021). Roles of artificial intelligence in construction engineering and management: A critical review and future trends. Automation in Construction, 122, 103517.

Pan, Y., & Zhang, L. (2023). Integrating BIM and AI for smart construction management: Current status and future directions. Archives of Computational Methods in Engineering, 30(2), 1081-1110.

Panya, D. S., Kim, T., & Choo, S. (2023). An interactive design change methodology using a BIM-based Virtual Reality and Augmented Reality. Journal of Building Engineering, 68, 106030.

Parker, D., & Wood, A. (Eds.). (2013). The tall buildings reference book. Routledge.

Pellas, N., Mystakidis, S., & Kazanidis, I. (2021). Immersive Virtual Reality in K-12 and Higher Education: A systematic review of the last decade scientific literature. Virtual Reality, 25(3), 835-861.

Persson, H., Åhman, H., Yngling, A. A., & Gulliksen, J. (2015). Universal design, inclusive design, accessible design, design for all: different concepts—one goal? On the concept of accessibility—historical, methodological and philosophical aspects. Universal Access in the Information Society, 14, 505-526.

Peters, K., & Halcomb, E. (2015). Interviews in qualitative research. Nurse Researcher (2014+), 22(4), 6.

Pena, M. L. C., Carballal, A., Rodríguez-Fernández, N., Santos, I., & Romero, J. (2021). Artificial intelligence applied to conceptual design. A review of its use in architecture. Automation in Construction, 124, 103550.

Perring, D. (2015). Recent advances in the understanding of Roman London.

Peters, K., Elands, B., & Buijs, A. (2010). Social interactions in urban parks: Stimulating social cohesion?. Urban forestry & urban greening, 9(2), 93-100.

Peters, T., & Halleran, A. (2021). How our homes impact our health: using a COVID-19 informed approach to examine urban apartment housing. Archnet-IJAR: International journal of architectural research, 15(1), 10-27.

Pham, H. C., Dao, N., Pedro, A., Le, Q. T., Hussain, R., Cho, S., & Park, C. S. I. K. (2018). Virtual field trip for mobile construction safety education using 360-degree panoramic virtual reality. International Journal of Engineering Education, 34(4), 1174-1191.

Phang, S. Y., & Helble, M. (2016). Housing policies in Singapore.

Philo, C., & Wilbert, C. (2004). Animal spaces, beastly places. Routledge.

Picon, A. (2010). Digital culture in architecture. In Digital Culture in Architecture. Birkhäuser.

Pinheiro, M. D., & Luís, N. C. (2020). COVID-19 could leverage a sustainable built environment. Sustainability, 12(14), 5863.

Pineo, H. (2022). Towards healthy urbanism: inclusive, equitable and sustainable (THRIVES)–an urban design and planning framework from theory to praxis. Cities & health, 6(5), 974-992.

Pinto, F., & Akhavan, M. (2022). Scenarios for a Post-Pandemic City: urban planning strategies and challenges of making "Milan 15-minutes city". Transportation research procedia, 60, 370-377.

PLACE, C., & WHARF, C. (2016). Current practice. Timber Gridshells: Architecture, Structure and Craft, 219.

Pollio, H. R., Henley, T. B., & Thompson, C. J. (1997). The phenomenology of everyday life: Empirical investigations of human experience. Cambridge University Press.

Pomeroy, J. (2012). Room at the top—the roof as an alternative habitable/social space in the Singapore context. Journal of Urban Design, 17(3), 413-424.

Pomeroy, J. (2013). The Skycourt and Skygarden: Greening the urban habitat. Routledge.

Pope, H. (2018). Introduction to virtual and augmented reality. Library Technology Reports, 54(6), 5-7.

Portman, M. E., Natapov, A., & Fisher-Gewirtzman, D. (2015). To go where no man has gone before: Virtual reality in architecture, landscape architecture and environmental planning. Computers, Environment and Urban Systems, 54, 376-384.

Potts, J. R., & Lewis, M. A. (2014). How do animal territories form and change? Lessons from 20 years of mechanistic modelling. Proceedings of the Royal Society B: Biological Sciences, 281(1784), 20140231.

Pouso, S., Borja, Á., Fleming, L. E., Gómez-Baggethun, E., White, M. P., & Uyarra, M. C. (2021). Contact with blue-green spaces during the COVID-19 pandemic lockdown beneficial for mental health. Science of The Total Environment, 756, 143984.

Powers, J. C., Bieliaieva, K., Wu, S., & Nam, C. S. (2015). The human factors and ergonomics of P300-based brain-computer interfaces. Brain sciences, 5(3), 318-354.

Pozoukidou, G., & Chatziyiannaki, Z. (2021). 15-Minute City: Decomposing the new urban planning eutopia. Sustainability, 13(2), 928.

Prabhakaran, A., Mahamadu, A. M., & Mahdjoubi, L. (2022). Understanding the challenges of immersive technology use in the architecture and construction industry: A systematic review. Automation in Construction, 137, 104228.

Pultarova, T. (2017). Better hold your breath-London's killer air [Built Environment Pollution]. Engineering & Technology, 12(4), 42-45.

Punter, J. V. (1990). The privatisation of the public realm. Planning Practice and Research, 5(3), 9-16.

Qian, Z. (2010). Without zoning: Urban development and land use controls in Houston. Cities, 27(1), 31-41.

Rabbitts, P. (2015). Hyde Park: The People's Park. Amberley Publishing Limited.

Radiah, R., Mäkelä, V., Prange, S., Rodriguez, S. D., Piening, R., Zhou, Y., ... & Alt, F. (2021). Remote VR studies: a framework for running virtual reality studies remotely via participant-owned HMDs. ACM Transactions on Computer-Human Interaction (TOCHI), 28(6), 1-36.

Rahimian, F. P., Chavdarova, V., Oliver, S., Chamo, F., & Amobi, L. P. (2019). OpenBIM-Tango integrated virtual showroom for offsite manufactured production of self-build housing. Automation in Construction, 102, 1-16.

Rahimian, F. P., Seyedzadeh, S., Oliver, S., Rodriguez, S., & Dawood, N. (2020). On-demand monitoring of construction projects through a game-like hybrid application of BIM and machine learning. Automation in Construction, 110, 103012.

Raji, B., Tenpierik, M. J., & Van Den Dobbelsteen, A. (2015). The impact of greening systems on building energy performance: A literature review. Renewable and Sustainable Energy Reviews, 45, 610-623.

Ravindranath, S. S., & Menon, S. J. (2018). Exploring new paradigms in high-density vertical hybrids. International journal of high-rise buildings, 7(2), 111-125.

Reed, M. S. (2008). Stakeholder participation for environmental management: a literature review. Biological conservation, 141(10), 2417-2431.

Regoeczi, W. C. (2002). The impact of density: The importance of nonlinearity and selection on flight and fight responses. Social Forces, 81(2), 505-530.

Regoeczi, W. C. (2008). Crowding in context: An examination of the differential responses of men and women to high-density living environments. Journal of Health and Social Behavior, 49(3), 254-268.

Reidenberg, J. R. (2014). Privacy in public. U. Miami L. Rev., 69, 141.

Reike, S. (2015). The Promise of Public Realm: Urban Space in the Skyscraper City. Global Interchanges: Resurgence of the Skyscraper City, 246-251.

Reinwald, F., Haluza, D., Pitha, U., & Stangl, R. (2021). Urban green infrastructure and green open spaces: An issue of social fairness in times of COVID-19 crisis. Sustainability, 13(19), 10606.

Rivera, E., Timperio, A., Loh, V. H., Deforche, B., & Veitch, J. (2021). Critical factors influencing adolescents' active and social park use: A qualitative study using walk-along interviews. Urban Forestry & Urban Greening, 58, 126948.

Ritter III, K. A., & Chambers, T. L. (2022). Three-dimensional modeled environments versus 360 degree panoramas for mobile virtual reality training. Virtual Reality, 26(2), 571-581.

Roaf, S. (2009). The sustainability of high density. In Designing high-density cities (pp. 60-72). Routledge.

Robinson, J., Harrison, P., Shen, J., & Wu, F. (2021). Financing urban development, three business models: Johannesburg, Shanghai and London. Progress in Planning, 154, 100513.

Robinson, K. S. (2020). The coronavirus is rewriting our imaginations. The New Yorker, 1.

Rokhsaritalemi, S., Sadeghi-Niaraki, A., & Choi, S. M. (2020). A review on mixed reality: Current trends, challenges and prospects. Applied Sciences, 10(2), 636.

Rorty, R. (1999). Philosophy and social hope. Penguin UK.

Rossi, S., Viola, I., Toni, L., & Cesar, P. (2021). From 3-DoF to 6-DoF: New Metrics to Analyse Users Behaviour in Immersive Applications. arXiv preprint arXiv:2112.09402.

Rossi, S., Viola, I., Toni, L., & Cesar, P. (2021, September). A new challenge: Behavioural analysis of 6-DoF user when consuming immersive media. In 2021 IEEE International Conference on Image Processing (ICIP) (pp. 3423-3427). IEEE.

Rossini, F., & Yiu, M. H. L. (2021). Public open spaces in private developments in Hong Kong: new spaces for social activities?. Journal of Urbanism: International Research on Placemaking and Urban Sustainability, 14(2), 237-261.

Rotroff, S. I. (1997). The Athenian Agora. Hellenistic pottery. Athenian and imported wheelmade table ware and related materials.

Roupé, M. (2013). Development and implementations of virtual reality for decision-making in urban planning and building design. Chalmers Tekniska Hogskola (Sweden).

Roupé, M., Johansson, M., Maftei, L., Lundstedt, R., & Viklund-Tallgren, M. (2020). Virtual collaborative design environment: supporting seamless integration of multitouch table and immersive VR. Journal of Construction Engineering and Management, 146(12), 04020132.

Rowe, P. G. (2009). The spatial transformation and restructuring of American Cities. In Making the Metropolitan Landscape (pp. 23-38). Routledge.

Rowe, P. G. (1991). Design thinking. MIT press.

Rubiera-Morollón, F., & Garrido-Yserte, R. (2020). Recent literature about urban sprawl: A renewed relevance of the phenomenon from the perspective of environmental sustainability. Sustainability, 12(16), 6551.

Rubio-Tamayo, J. L., Gertrudix Barrio, M., & García García, F. (2017). Immersive environments and virtual reality: Systematic review and advances in communication, interaction and simulation. Multimodal Technologies and Interaction, 1(4), 21.

Saßmannshausen, S. M., Radtke, J., Bohn, N., Hussein, H., Randall, D., & Pipek, V. (2021, June). Citizen-centered design in urban planning: How augmented reality can be used in citizen participation processes. In Designing Interactive Systems Conference 2021 (pp. 250-265).

Saelens, B. E., Sallis, J. F., & Frank, L. D. (2003). Environmental correlates of walking and cycling: findings from the transportation, urban design, and planning literatures. Annals of behavioral medicine, 25(2), 80-91.

Safikhani, S., Keller, S., Schweiger, G., & Pirker, J. (2022). Immersive virtual reality for extending the potential of building information modeling in architecture, engineering, and construction sector: systematic review. International Journal of Digital Earth, 15(1), 503-526.

Sakai, A. (2011). 'Re-assessing'London's squares: the development of preservation policy 1880-1931. The Town Planning Review, 615-637.

Sallis, J. F., Bull, F., Burdett, R., Frank, L. D., Griffiths, P., Giles-Corti, B., & Stevenson, M. (2016). Use of science to guide city planning policy and practice: how to achieve healthy and sustainable future cities. The lancet, 388(10062), 2936-2947.

Salami, S. F., Isah, A. D., & Muhammad, I. B. (2021). Critical indicators of sustainability for mixed-use buildings in Lagos, Nigeria. Environmental and Sustainability Indicators, 9, 100101.

Samant, S. (2019). Cities in the Sky: Elevating Singapore's Urban Spaces. International Journal of High-Rise Buildings, 8(2), 137-154.

Samant, S., & Menon, S. (2018). Exploring new paradigms in high-density vertical hybrids high-rise buildings exploring new paradigms in high-density vertical hybrids. Int. J. High-Rise Build, 7(2), 111-125.

Samant, S., & Hsi-En, N. (2017). A tale of two Singapore sky gardens. CTBUH Journal, (3), 26-31.

Sanchez-Sepulveda, M. V., Torres-Kompen, R., Fonseca, D., & Franquesa-Sanchez, J. (2019). Methodologies of learning served by virtual reality: A case study in urban interventions. Applied Sciences, 9(23), 5161.

Sanchez-Sepulveda, M., Fonseca, D., Franquesa, J., & Redondo, E. (2019). Virtual interactive innovations applied for digital urban transformations. Mixed approach. Future Generation Computer Systems, 91, 371-381.

Sanders, E. B. N., & Stappers, P. J. (2008). Co-creation and the new landscapes of design. Co-design, 4(1), 5-18.

Sanders, E. B. N., Brandt, E., & Binder, T. (2010, November). A framework for organizing the tools and techniques of participatory design. In Proceedings of the 11th biennial participatory design conference (pp. 195-198).

Sanders, E. B. N., & Stappers, P. J. (2014). Probes, toolkits and prototypes: three approaches to making in codesigning. CoDesign, 10(1), 5-14.

Sandelowski, M., & Barroso, J. (2003). Classifying the findings in qualitative studies. Qualitative health research, 13(7), 905-923.

Sanoff, H. (2000). Community participation methods in design and planning. John Wiley & Sons.

Saredakis, D., Szpak, A., Birckhead, B., Keage, H. A., Rizzo, A., & Loetscher, T. (2020). Factors associated with virtual reality sickness in head-mounted displays: a systematic review and meta-analysis. Frontiers in human neuroscience, 14, 96.

Sartorio, F. S., Aelbrecht, P., Kamalipour, H., & Frank, A. (2021). Towards an antifragile urban form: a research agenda for advancing resilience in the built environment. Urban Design International, 26, 135-158.

Saunders, M., Lewis, P., & Thornhill, A. (2009). Research methods for business students. Pearson education.

Sbriglio, J. (2004). Le Corbusier: L'Unité d'habitation de Marseille/The Unité d'Habitation in Marseilles: et les autres Unités d'habitation à Rezé-les-Nantes, Berlin, Briey en Forêt et Firminy/and the four other unité blocks. Springer Science & Business Media.

Schertz, K. E., & Berman, M. G. (2019). Understanding nature and its cognitive benefits. Current Directions in Psychological Science, 28(5), 496-502.

Schneider, O., MacLean, K., Swindells, C., & Booth, K. (2017). Haptic experience design: What hapticians do and where they need help. International Journal of Human-Computer Studies, 107, 5-21.

Schmalstieg, D., & Hollerer, T. (2016). Augmented reality: principles and practice. Addison-Wesley Professional.

Schoenefeldt, H. (2016). Question Time. CIBSE Journal, 2016(9), 70-74.

Schröpfer, T., Menz, S., Schröpfer, T., & Menz, S. (2019). Frameworks and Guidelines Promoting High-Rise Greenery. Dense and Green Building Typologies: Design Perspectives, 13-19.

Schutz, A. (1967). The phenomenology of the social world. Northwestern UniversityPress.[WSB](1971) On multiple realities. Collected papers, 1, 20759.

Schiavi, B., Havard, V., Beddiar, K., & Baudry, D. (2022). BIM data flow architecture with AR/VR technologies: Use cases in architecture, engineering and construction. Automation in Construction, 134, 104054.

Schiffenbauer, A. I., Brown, J. E., Perry, P. L., Shulack, L. K., & Zanzola, A. M. (1977). The relationship between density and crowding: Some architectural modifiers. Environment and Behavior, 9(1), 3-14.

Schmidt, S., & Németh, J. (2010). Space, place and the city: Emerging research on public space design and planning. Journal of Urban Design, 15(4), 453-457.

Schreier, M. (2014, January). Varianten qualitativer Inhaltsanalyse: ein wegweiser im dickicht der Begrifflichkeiten. In Forum Qualitative Sozialforschung/Forum: Qualitative Social Research (Vol. 15, No. 1).

Schrom-Feiertag, H., Stubenschrott, M., Regal, G., Matyus, T., & Seer, S. (2020, May). An interactive and responsive virtual reality environment for participatory urban planning. In Proceedings of the 11th Annual Symposium on Simulation for Architecture and Urban Design (pp. 1-7).

Schwarzkopf, S., & Backsell, J. I. (2021). The nomos of the freeport. Environment and Planning D: Society and Space, 39(2), 328-346.

Seamon, D. (2000). Phenomenology, place, environment, and architecture: A review of the literature. Phenomenology Online, 36, 1-29.

Selinger, E. M., & Crease, R. P. (2002). Dreyfus on expertise: the limits of phenomenological analysis. Continental Philosophy Review, 35(3), 245-279.

Sennett, R. (2020). The public realm. In Being Urban (pp. 35-58). Routledge.

Sennett, R. (1998). The spaces of democracy (pp. 40-1). University of Michigan, College of Architecture+ Urban Planning.

Sennett, R., 1974. The Fall of Public Man. New York: Norton & Company

Shabbir, J., & Anwer, T. (2018). Artificial intelligence and its role in near future. arXiv preprint arXiv:1804.01396.

Shaftoe, H. (2012). Convivial urban spaces: Creating effective public places. Routledge.

Sharifi, A., & Khavarian-Garmsir, A. R. (2020). The COVID-19 pandemic: Impacts on cities and major lessons for urban planning, design, and management. Science of the total environment, 749, 142391.

Sharifi, A. (2019). Urban form resilience: A meso-scale analysis. Cities, 93, 238-252.

Shannon, T. (2017). Unreal Engine 4 for design visualization: Developing stunning interactive visualizations, animations, and renderings. Addison-Wesley Professional.

Shen, J., Xiang, H., Luna, J., Grishchenko, A., Patterson, J., Strouse, R. V., ... & Lin, E. J. D. (2020). Virtual reality–based executive function rehabilitation system for children with traumatic brain injury: design and usability study. JMIR serious games, 8(3), e16947.

Shin, J., & Lee, K. (2022). Incorporating real-world object into virtual reality: using mobile device input with augmented virtuality. Multimedia Tools and Applications, 1-28.

Sherman, W. R., & Craig, A. B. (2018). Understanding virtual reality: Interface, application, and design. Morgan Kaufmann.

Shroff, R. (2020). The Tall Building Strategically Reconsidered - Seattle 2030: The Post-Crisis Tower. CTBUH Journal, (4).

Shelton, B., Karakiewicz, J., & Kvan, T. (2013). The making of Hong Kong: from vertical to volumetric. Routledge.

Sieber, J., 1993, 'The ethics and politics of sensitive research', in: C. Renzetti and R.M. Lee, (eds.), Researching sensitive topics, Sage, London.

Sinha, A. (2014). Slow landscapes of elevated linear parks: Bloomingdale Trail in Chicago. Studies in the History of Gardens & Designed Landscapes, 34(2), 113-122.

Siong, N. B., Gwee, J., & Mak, C. (2013). Case study 1: Growing a city in a garden. In Case Studies in Public Governance (pp. 11-63). Routledge.

Sitte, C. (1889). The Relationship between Buildings, Monuments, and Public Squares and The Enclosed Character of the Public Square. The City Reader (1996), Routledge, New York, USA.

Sky-Garden, 2015. Sky Garden Visitor Rules & Regulations. [Online] Available at: https://skygarden.london/terms-conditions/ [Accessed 4 May 2020].

Slater, M., Gonzalez-Liencres, C., Haggard, P., Vinkers, C., Gregory-Clarke, R., Jelley, S., ... & Silver, J. (2020). The ethics of realism in virtual and augmented reality. Frontiers in Virtual Reality, 1, 1.

Slater, M., & Wilbur, S. (1997). A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments. Presence: Teleoperators & Virtual Environments, 6(6), 603-616.

Šmíd, A. (2017). Comparison of unity and unreal engine. Czech Technical University in Prague, 41-61.

Smith, A. (2015). Events in the city: Using public spaces as event venues. Routledge.

Smith, J. A. (2015). Qualitative psychology: A practical guide to research methods. Qualitative psychology, 1-312.

Smith, M. S. (2005). The garden squares of Boston.

Snelling, C., Colebrook, C., & Murphy, L. (2016). Homesharing & London's housing market. London: Institute for Public Policy Research.

Sidani, A., Dinis, F. M., Sanhudo, L., Duarte, J., Santos Baptista, J., Pocas Martins, J., & Soeiro, A. (2021). Recent tools and techniques of BIM-based virtual reality: A systematic review. Archives of Computational Methods in Engineering, 28(2), 449-462.

Simonsen, J., & Robertson, T. (Eds.). (2013). Routledge international handbook of participatory design (Vol. 711). New York: Routledge.

Sinn, E., 1987. Kowloon Walled City: Its origin and early history. Journal of the Hong Kong Branch of the Royal Asiatic Society, pp.30-45.

Sitte, C. (1889). City planning according to artistic principles. In Camillo Sitte: The birth of modern city planning (pp. 129-332).

Sönmez, N. O. (2018). A review of the use of examples for automating architectural design tasks. Computer-Aided Design, 96, 13-30.

Stals, A., & Caldas, L. (2022). State of XR research in architecture with focus on professional practice–a systematic literature review. Architectural Science Review, 65(2), 138-146.

Stauskis, G. (2014). Development of methods and practices of virtual reality as a tool for participatory urban planning: a case study of Vilnius City as an example for improving environmental, social and energy sustainability. Energy, Sustainability and Society, 4, 1-13

Steed, A., Pan, Y., Zisch, F., & Steptoe, W. (2016, March). The impact of a self-avatar on cognitive load in immersive virtual reality. In 2016 IEEE virtual reality (VR) (pp. 67-76). IEEE.

Stelzle, B., Jannack, A., & Noennig, J. R. (2017). Co-design and co-decision: Decision making on collaborative design platforms. Procedia computer science, 112, 2435-2444.

Steuer, J., Biocca, F., & Levy, M. R. (1995). Defining virtual reality: Dimensions determining telepresence. Communication in the age of virtual reality, 33, 37-39.

Stokols, D., 1972. On the distinction between density and crowding: some implications for future research. Psychological review, 79(3), p.275.

Stone, D. (2013). Knowledge actors and transnational governance: The private-public policy nexus in the global agora. Springer.

Sutherland, I. E. (1965). The ultimate display. Multimedia: From wagner to virutal reality.

Sze, J. (2006). Noxious New York: The racial politics of urban health and environmental justice. MIT press.

Taib, N., Abdullah, A., Fadzil, S. F. S., & Yeok, F. S. (2010). An assessment of thermal comfort and users' perceptions of landscape gardens in a high-rise office building. Journal of sustainable development, 3(4), 153.

Talen, E. 2011. Sprawl retrofit: sustainable urban form in unsustainable. Environment and Planning B: Planning and Design, 38, 952 -978

Taylor, J. R., & Lovell, S. T. (2021). Designing multifunctional urban agroforestry with people in mind. Urban Agriculture & Regional Food Systems, 6(1), e20016.

The Mayor of London, 2016. The London Plan , London : Greater London Authority .

The Mayor of London, 2016. A City for All Londoners, London: Greater London Authority.

The Mayor of London, 2020. PUBLIC LONDON CHARTER, London: The London Assembly.

Thompson, C. W. (2002). Urban open space in the 21st century. Landscape and urban planning, 60(2), 59-72.

Thompson, J. B. (1993). The theory of the public sphere. Theory, culture & society, 10(3), 173-189.

Thurzo, A., Strunga, M., Urban, R., Surovková, J., & Afrashtehfar, K. I. (2023). Impact of artificial intelligence on dental education: A review and guide for curriculum update. Education Sciences, 13(2), 150.

Tian, Y., & Jim, C. Y. (2011). Factors influencing the spatial pattern of sky gardens in the compact city of Hong Kong. Landscape and Urban Planning, 101(4), 299-309.

Timm, S., Dearborn, L., & Pomeroy, J. (2018). Nature and the City: Measuring the Attention Restoration Benefits of Singapore's Urban Vertical Greenery. Technology| Architecture+ Design, 2(2), 240-249.

Toland, I. 2001. 4 Unites LC: Fragments of Radiant Dream. www.architects.nsw.gov.au/download/BHTS/TolandIsabelle_4_unites_LC_BHTS_1999.pdf

Tomkins, L., & Eatough, V. (2013). The feel of experience: Phenomenological ideas for organizational research. Qualitative Research in Organizations and Management: An International Journal, 8(3), 258-275.

Tonkiss, F., 2005. Space, the city and social theory: Social relations and urban forms. Cambridge: Polity Press.

Triguero Mas, M., Anguelovski, I., Cirac-Claveras, J., Connolly, J., Vazquez, A., Urgell Plaza, F., ... & Cole, H. (2020). Quality of life benefits of urban rooftop gardening for people with intellectual disabilities or mental health disorders. Prev Chronic Dis. 2020; 17: E126.

Tuffour, I. (2017). A critical overview of interpretative phenomenological analysis: A contemporary qualitative research approach. Journal of healthcare communications, 2(4), 52.

Ugolini, F., Massetti, L., Calaza-Martínez, P., Cariñanos, P., Dobbs, C., Ostoić, S. K., ... & Šaulienė, I. (2020). Effects of the COVID-19 pandemic on the use and perceptions of urban green space: An international exploratory study. Urban Forestry & Urban Greening, 56, 126888. https://doi.org/10.1016/j.ufug.2020.126888

Urban Redevelopment Authority (URA). (2014). Circular package: Landscaping for urban spaces and high-rises (LUSH) 2.0 programme

Valls, F., Redondo, E., Fonseca, D., Garcia-Almirall, P., & Subirós, J. (2016). Videogame technology in architecture education. In Human-Computer Interaction. Novel User Experiences: 18th International Conference, HCI International 2016, Toronto, ON, Canada, July 17-22, 2016. Proceedings, Part III 18 (pp. 436-447). Springer International Publishing.

Van den Berg, M., Van Poppel, M., Van Kamp, I., Andrusaityte, S., Balseviciene, B., Cirach, M., ... & Maas, J. (2016). Visiting green space is associated with mental health and vitality: A cross-sectional study in four european cities. Health & place, 38, 8-15.

Van Leeuwen, J. P., Hermans, K., Jylhä, A., Quanjer, A. J., & Nijman, H. (2018, November). Effectiveness of virtual reality in participatory urban planning: A case study. In Proceedings of the 4th Media Architecture Biennale Conference (pp. 128-136).

Van Manen, M. (2023). Phenomenology of practice: Meaning-giving methods in phenomenological research and writing. Taylor & Francis.

Varna, G., & Tiesdell, S. (2010). Assessing the publicness of public space: The star model of publicness. Journal of urban design, 15(4), 575-598.

Varma, P., Junge, M., Meaklim, H., & Jackson, M. L. (2021). Younger people are more vulnerable to stress, anxiety and depression during COVID-19 pandemic: A global cross-sectional survey. Progress in Neuro-Psychopharmacology and Biological Psychiatry, 109, 110236.

Vaughan, A., 2015. Nearly 9,500 people die each year in London because of air pollution – study, London: The Guardian.

Veitch, J., Flowers, E., Ball, K., Deforche, B., & Timperio, A. (2020). Designing parks for older adults: A qualitative study using walk-along interviews. Urban Forestry & Urban Greening, 54, 126768.

Ververidis, D., Nikolopoulos, S., & Kompatsiaris, I. (2022). A Review of Collaborative Virtual Reality Systems for the Architecture, Engineering, and Construction Industry. Architecture, 2(3), 476-496.

Viñoly, R., Blomberg, C., & Blanes, M. (2015). Challenges and Benefits of Integrating Public Space into Tall Buildings. CTBUH Research Paper, 282-287.

Vujcic, M., Tomicevic-Dubljevic, J., Grbic, M., Lecic-Tosevski, D., Vukovic, O., & Toskovic, O. (2017). Nature based solution for improving mental health and well-being in urban areas. Environmental research, 158, 385-392.

Wang, S., Bolling, K., Mao, W., Reichstadt, J., Jeste, D., Kim, H. C., & Nebeker, C. (2019, April). Technology to support aging in place: Older adults' perspectives. In Healthcare (Vol. 7, No. 2, p. 60). MDPI.

Wang, X., & Schnabel, M. A. (Eds.). (2008). Mixed reality in architecture, design, and construction. Springer Science & Business Media.

Wall, E. (2022). Contesting public spaces: social lives of urban redevelopment in London. Taylor & Francis.

Walton, H., Dajnak, D., Beevers, S., Williams, M., Watkiss, P., & Hunt, A. (2015). Understanding the health impacts of air pollution in London. London: Kings College London, Transport for London and the Greater London Authority, 1(1), 6-14.

Warner, M. and Calhoun, C., 2003. The mass public and the mass subject. American Literary Studies: A Methodological Reader, pp.243-263

Wates, N. (2014). The community planning handbook: how people can shape their cities, towns and villages in any part of the world. Routledge

Watson, S. (2006). City Publics: The (dis)enchantments of urban encounters. London [etc.], Routledge.

Watson, E., Viana, T., & Zhang, S. (2023). Augmented Behavioral Annotation Tools, with Application to Multimodal Datasets and Models: A Systematic Review. AI, 4(1), 128-171.

Watt, P., & Minton, A. (2016). London's housing crisis and its activisms: Introduction. City, 20(2), 204-221.

Webb, R., Bai, X., Smith, M. S., Costanza, R., Griggs, D., Moglia, M., ... & Thomson, G. (2018). Sustainable urban systems: Co-design and framing for transformation. Ambio, 47, 57-77.

Wei, D., Talwar, V., & Lin, D. (2021). Neural circuits of social behaviors: innate yet flexible. Neuron, 109(10), 1600-1620.

Weinbaum, S. G. (2016). Pygmalion's spectacles. Simon and Schuster.

Welage, N., & Liu, K. P. (2011). Wheelchair accessibility of public buildings: a review of the literature. Disability and Rehabilitation: Assistive Technology, 6(1), 1-9.

Wen, J., & Gheisari, M. (2020). Using virtual reality to facilitate communication in the AEC domain: A systematic review. Construction Innovation, 20(3), 509-542.

Wen, J., & Gheisari, M. (2021). VR-Electricians: Immersive storytelling for attracting students to the electrical construction industry. Advanced Engineering Informatics, 50, 101411.

Whitehead, C. M., & Goering, J. (2021). Local affordable housing dynamics in two global cities: patterns and possible lessons?. International Journal of Urban Sciences, 25(sup1), 241-265.

White, J. (2016). London in the twentieth century: a city and its people. Random House.

Whyte, W. H. (1980). The social life of small urban spaces. Conservation Foundation.

Williams, K. and Green, S., 2001. Literature review of public space and local environments for the cross-cutting review. Oxford Brookes University, Oxford Centre for Sustainable Development.

Willis, C. (1992). The Empire State Building. Landscape of Modernity: Essays on New York City, 1900-1940, 160.

Willis, D. G., Sullivan-Bolyai, S., Knafl, K., & Cohen, M. Z. (2016). Distinguishing features and similarities between descriptive phenomenological and qualitative description research. Western journal of nursing research, 38(9), 1185-1204.

Wilson, A., Tewdwr-Jones, M., & Comber, R. (2019). Urban planning, public participation and digital technology: App development as a method of generating citizen involvement in local planning processes. Environment and Planning B: Urban Analytics and City Science, 46(2), 286-302.

Wilson, E. O. (1986). Biophilia. Harvard university press.

Wilson, E. O. (2017). Biophilia and the conservation ethic. In Evolutionary perspectives on environmental problems (pp. 250-258). Routledge

Wilsons, M. & Moore, H., 2020. Exploring London's public realm, London: Greater London Authority.

Winge, L., & Lamm, B. (2019). Making the red dot on the map-bringing children's perspectives to the city planning agenda through visible co-design actions in public spaces. Cities & health, 3(1-2), 99-110.

Wolf, M., Söbke, H., & Wehking, F. (2020). Mixed Reality Media-Enabled Public Participation in Urban Planning: A Literature Review. Augmented reality and virtual reality: changing realities in a dynamic world, 125-138.

Wong, M. S., Hassell, R., & Phua, H. W. (2018). Oasia Hotel Downtown, Singapore: A Tall Prototype for the Tropics. CTBUH Research Paper, (III), 12-19.

Wong, N. H., et al. (2010). Perception studies of vertical greenery systems in Singapore. Journal of Urban Planning and Development, 136(4), 330-338.

Wood, A. (2014, September). Rethinking the skyscraper in the ecological age: Design principles for a new high-rise vernacular. In Proceedings of the CTBUH 2014 Shanghai conference «Future cities: Towards sustainable vertical urbanism». Shanghai, China. 16th (pp. 26-38).

Wood, A., 2003. Pavements in the sky: the skybridge in tall buildings, Architectural Research Quarterly. Cambridge University Press, 7(3-4), pp. 325–332.

Wood, A., & Henry, S. (2016). Best tall buildings: CTBUH awards: A global overview of 2016 skyscrapers.

Wood, A., & Safarik, D. (2019). Skybridges: A history and a view to the near future. International Journal of High-Rise Buildings, 8(1), 1-18.

Worthington, M. (2013). Differences between phenomenological research and a basic qualitative research design.

Woudstra, J. (2000). The Corbusian Landscape: Arcadia or No Man's Land?. Garden History, 28(1), 135-151.

Wu, A. N., Stouffs, R., & Biljecki, F. (2022). Generative Adversarial Networks in the built environment: A comprehensive review of the application of GANs across data types and scales. Building and Environment, 109477.

Wu, N., & Silva, E. A. (2010). Artificial intelligence solutions for urban land dynamics: a review. Journal of Planning Literature, 24(3), 246-265.

Xie, J., Luo, S., Furuya, K., & Sun, D. (2020). Urban parks as green buffers during the COVID-19 pandemic. Sustainability, 12(17), 6751.

Xue, F., Wu, Z., Tong, J., Zheng, J., & Li, C. (2017). Effect of combination of high-intensity ultrasound treatment and dextran glycosylation on structural and interfacial properties of buckwheat protein isolates. Bioscience, Biotechnology, and Biochemistry, 81(10), 1891-1898.

Yang, J., Yu, Q., & Gong, P. (2015). Quantifying air pollution removal by green roofs in Chicago. Atmospheric Environment, 115, 223-233. https://doi.org/10.1016/j.atmosenv.2015.05.062

Yang, L., Zhang, L., Philippopoulos-Mihalopoulos, A., Chappin, E. J., & van Dam, K. H. (2021). Integrating agent-based modeling, serious gaming, and co-design for planning transport infrastructure and public spaces. Urban Design International, 26(1), 67-81.

Yaqoob, A., Bi, T., & Muntean, G. M. (2020). A survey on adaptive 360 video streaming: Solutions, challenges and opportunities. IEEE Communications Surveys & Tutorials, 22(4), 2801-2838.

Yeang, K. (2008, March). Ecoskyscrapers and Ecomimesis: New tall building typologies. In Proceedings of the 8th CTBUH World Congress on Tall & Green: Typology for a Sustainable Urban Future, Dubai, UAE (pp. 3-5).

Yeang, K. (2002). Reinventing the skyscraper: a vertical theory of urban design. Academy Press.

Yeang, K., & Powell, R. (2007). Designing the ecoskyscraper: premises for tall building design. The Structural Design Of Tall and Special Buildings, 16(4), 411-427.

Yeang, K., & Richards, I. (2007). Eco Skyscrapers I. Images Publishing.

Yeh, A. G., & Xu, J. (2011). China's post-reform urbanization: Retrospect, policies and trends. Population and Development Review, 37, 573-594.

Yigitcanlar, T., Corchado, J. M., Mehmood, R., Li, R. Y. M., Mossberger, K., & Desouza, K. (2021). Responsible urban innovation with local government artificial intelligence (AI): A conceptual framework and research agenda. Journal of Open Innovation: Technology, Market, and Complexity, 7(1), 71.

Yin, J., Hinchet, R., Shea, H., & Majidi, C. (2021). Wearable soft technologies for haptic sensing and feedback. Advanced Functional Materials, 31(39), 2007428.

Young, K., 1990. Learning Through Landscapes: Using School Grounds as an Educational Resource. Green Brick Road, 429 Danforth Ave., Ste.# 408, Toronto, Ontario, Canada M4K 1P1.

Yu, C. P., Lee, H. Y., & Luo, X. Y. (2018). The effect of virtual reality forest and urban environments on physiological and psychological responses. Urban forestry & urban greening, 35, 106-114.

Yu, R., Gu, N., Lee, G., & Khan, A. (2022). A Systematic Review of Architectural Design Collaboration in Immersive Virtual Environments. Designs, 6(5), 93.

Yuen, B., & Yeh, A. G. (Eds.). (2011). High-rise living in Asian cities (pp. 1-8). Dordrecht, Heidelberg, London, New York: Springer.

Yuen, B., & Hien, W. N. (2005). Resident perceptions and expectations of rooftop gardens in Singapore. Landscape and urban planning, 73(4), 263-276.

Yuen, B., Yeh, A., Appold, S. J., Earl, G., Ting, J., & Kurnianingrum Kwee, L. (2006). High-rise living in Singapore public housing. Urban Studies, 43(3), 583-600.

Zhao, P., & Li, P. (2017). Rethinking the relationship between urban development, local health and global sustainability. Current Opinion in Environmental Sustainability, 25, 14-19.

Zaker, R., & Coloma, E. (2018). Virtual reality-integrated workflow in BIM-enabled projects collaboration and design review: a case study. Visualization in Engineering, 6(1), 1-15.

Zhang, C., Zeng, W., & Liu, L. (2021). UrbanVR: An immersive analytics system for context-aware urban design. Computers & Graphics, 99, 128-138.

Zhang, X. Q. (2016). The trends, promises and challenges of urbanisation in the world. Habitat international, 54, 241-252.

Zhang, X., & He, Y. (2020). What makes public space public? The chaos of public space definitions and a new epistemological approach. Administration & Society, 52(5), 749-770.

Zhang, Y., Azzali, S., Janssen, P., & Stouffs, R. (2018). Design for walkable neighbourhoods in Singapore using Form-based Codes. International Forum on Urbanism.

Zhang, Y., Liu, H., Kang, S. C., & Al-Hussein, M. (2020). Virtual reality applications for the built environment: Research trends and opportunities. Automation in Construction, 118, 103311.

Appendix A: Real Cognitive Experience Study

Participant Consent Form

Name of Study: Sustainable Vertical Urbanism - design and practice of vertical social spaces in coexistence with COVID 19 situation

Name of Researcher: Ahmed Ehab Abdelsalam Student ID: 20090457

Name of Participant:

By signing this form I confirm that (please initial the appropriate boxes):	**Initials**
I have read and understood the Participant Information Sheet, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study up until one year after the interview took place, without having to give a reason.	
Taking part in this study involves an interview and observations of the participant that will be recorded using audio/written notes. Audio recordings will be transcribed and recordings destroyed.	
Personal information collected about me that can identify me, such as my name or where I live, will not be shared beyond the study team.	
My words can be quoted in publications, reports, web pages and other research outputs.	
I give permission for the de-identified (anonymised) data that I provide to be used for future research and learning.	

I agree to take part in the study

______________________ ______________________ ________________

Name of Participant Signature Date

Faculty of Engineering

Department of Architecture and Built Environment

Sustainable Vertical Urbanism - design and practice of vertical social spaces in coexistence with COVID 19 situation

Direct Observation Study

Student Name: Ahmed Ehab Abdelsalam   Student ID: 20090457

The purpose of this study is to explore how people are using vertical social spaces in London before and during the pandemic. The method used in this study is direct observation at different times of the year. Fieldwork is essential for data collection to gather an understanding of how the space changed in terms of accessibility, circulation, and activities. The specific objectives are to analyse the physical experience of visitors and to examine the critical issues such as accessibility, circulation, activities, limitations of visitors, social distancing. The data collected will be stored in a secure location in accordance with University of Nottingham regulations, including the General Data Protection Regulation (GDPR) that came into force in May 2018.

Methods used in the study:

1. **Counting:** This is a commonly used tool in public life studies. Counting provides quantitative data that can be used to qualify projects. What is often counted is the number of people moving, and the number of people partaking in stationary activities. The counting method is useful for making comparisons before and after between different spaces over time or after the application of some changes.
2. **Behaviour Mapping:** This is the representation of people's reactions and activities, with drawings, signs, and symbols in the form of a map which includes types and frequency of human actions.
3. **Photographs and films**: Photographing is an essential observation tool to document and illustrate a particular situation. Pictures and video can describe situations showing the interaction between urban form and life. it’s a good tool fast freezing the situation for latter documentation and analysis.
4. **Test walks**: This method is important as the observer has the chance to notice problems and potentials for space and its surrounding area.

Data Collection Sheet:

The questions listed on the observation study timetable provide documentation and understanding about people behaviour in the space. The systematic questions divide visitors into subcategories and divide the variety of activities in order to get specific comparative data about people behaviour and the use of the space before and during the lockdown at different times of the year.

Detailed descriptive timetable for the observation study:

Five Questions	Vertical Social space Name – Date – Time		Notes & Graphical annotations
How many	Pedestrian flow (people)		
	Stationary activity (People)		
	Seating fixtures		
	Activities		
	Women		
Who	Who is using the space		
	Gender		
	Age		
Where	Where people move?		
	Where people stay?		
	Where are the activities?		
	Where are the entrances?		
	Where are the seating spaces?		
	What are the activities?	Types of Activities related to Function:	

What	Necessary activities	Shopping	
		Walking to bus	
		Working	
	Optional activities	Jogging	
		Sitting	
		Reading	
		Playing	
		Eating	
		Taking pictures	
		Relaxing	
	Social activities	Children playing	
		Greetings	
		Conversations	
		Common activities	
		Passive contact (listening and watching others)	
How Long	How long it takes people to cover certain distance?		
	How long people stay in a certain space?		
	How long did the activity last?		

Faculty of Engineering

Department of Architecture and Built Environment

PhD Case Study

Sustainable Vertical Urbanism - design and practice of vertical social spaces in coexistence with COVID 19 situation

Semi- structured Interview with visitors

Student Name: Ahmed Ehab Abdelsalam Student ID: 20090457

Data collection sheet:

The fieldwork takes place in **London's Sky Garden**, 20 Fenchurch Street, London and **Crossrail Place Roof Garden**, Canary Wharf, London. Participants will be the visitors of the space and they will be invited during the site observation study. The semi-structured interviews will be conducted with people from different age groups and the participants will be all aged 18 and above. The duration of the interviews is estimated to take around 30 minutes and participants will be recruited in both spaces. During the research, all data will be stored in a password protected file and stored in a locked filing cabinet and scanned to be stored digitally on a password-protected external hard drive. The researcher and supervisor will be the only person with access to the raw data.

Data collected from these semi-structured interviews will focus on exploring the physical experience of the space users. The study aims to investigate the relationship between visitor's behaviour and the design of the vertical social space. The specific objective is to analyse the types of social interaction that take place and what brings them about.

Semi- structured Interview with visitors

Location: Date: Time: Participant's details (Gender, Age Group): *The participants may not give their personal details at their absolute discretion*

1- Why did you choose to visit Crossrail Place Roof Garden / London's Sky Garden?

2- Have you been here before?

If yes,

- How often do you visit the space?
- How long do you usually stay?

3- How do you find the accessibility from the ground level?

4- How do you find the space circulation?

5- How do you find the level of publicity and security?

6- What kind of activities would you like to do here?

7- Do you have any concerns about the space design that you want to change?

If yes,

- Please indicate your concerns or design obstacles?

8- Would you like to add any other activities or design features?

If yes,

- What are the suggested activities?
- What are the suggested design features?

9- How would you describe your general experience today?

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Participant Information Sheet

Date: 31/05/2021

Title of Study: Sustainable Vertical Urbanism - design and practice of vertical social spaces in coexistence with COVID 19 situation

Name of Researcher: Ahmed Ehab Abdelsalam   Supervisor: Prof. Tim Heath

We would like to invite you to take part in our research study. Before you decide we would like you to understand why the research is being done and what it would involve for you. One of our team will go through the information sheet with you and answer any questions you have. Talk to others about the study if you wish. Ask us if there is anything that is not clear.

Participation in this study is entirely voluntary and you can withdraw at any point and without giving a reason.

What is the purpose of the study?

The purpose of this study is to explore how people are using vertical social spaces in London before and during the pandemic. The specific objectives are to analyse the physical experience of visitors and to examine the critical issues such as accessibility, circulation, activities, limitations of visitors, social distancing. The study aims to investigate the relationship between visitor's behaviour and the design of the vertical social space.

Why have I been invited?

You are being invited to take part because you are over 18 and present in the vertical public space (Crossrail Place Roof Garden / London's Sky Garden). I am inviting approximately 66 participants like you to take part.

Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a consent form (completion and return of a Questionnaire can be taken as implied consent). If you decide to take part, you are still free to withdraw at any time and without giving a reason. This would not affect your legal rights.

What will happen to me if I take part?

The process followed on this study is called *Direct Observation Study* and it seeks to examine the critical issues such as accessibility, circulation, activities, limitations of visitors, social distancing. Experience Journeys will be mapped, and participant's behaviour will be recorded for further data analysis. In addition, photographs and videos will be taken at different “locations” and “situations” without showing the identity of the participant.

I will conduct short semi structured interviews; ask questions related to the physical experience of the space users and the types of social interaction that take place. The conversations will be recorded and transcribed, after which the recordings will be deleted. The duration of the interviews is estimated to range between 10-15 minutes.

Expenses and payments

Participants will not be paid an allowance to participate in the study.

What are the possible disadvantages and risks of taking part?

There are no possible disadvantages, inconvenience or risks of taking part in the study.

What are the possible benefits of taking part?

We cannot promise the study will help you but the information we get from this study may improve the design of vertical social space, help experts to develop new suggested solutions for creating vertical social spaces that feel safe, operate effectively, and add value for users and developers and also address common challenges and community issues such as accessibility, circulation, activities, limitations of visitors, social distancing.

What if there is a problem?

If you have a concern about any aspect of this study, you should contact me and I will do my best to answer your questions. If you remain unhappy and wish to complain formally, you can do this by contacting the School Research Ethics Officer. All contact details are given at the end of this information sheet.

What will happen if I don’t want to carry on with the study?

Your participation is voluntary, and you are free to withdraw at any time, without giving any reason, and without your legal rights being affected.

Will my taking part in the study be kept confidential?

We will follow ethical and legal practice and all information about you will be handled in confidence.

If you join the study, the data collected for the study will be looked at by authorised persons from the University of Nottingham who are organising the research. They may also be looked at by authorised people to check that the study is being carried out correctly. All will have a duty of confidentiality to you as a research participant and we will do our best to meet this duty.

All information which is collected about you during the course of the research will be kept strictly confidential, stored in a secure and locked office, and on a password protected database. Any information about you which leaves the University will have your name and address removed (anonymised) and a unique code will be used so that you cannot be recognised from it. Anonymised data may also be stored in data archives for future researchers interested in this area.

Your personal data will be kept for 1 year after the end of the study so that we are able to contact you about the findings of the study and possible follow-up studies (unless you advise us that you do not wish to be contacted). All research data will be kept securely for 7 years. After this time your data will be disposed of securely. During this time all precautions will be taken by all those involved to maintain your confidentiality, only members of the research team will have access to your personal data.

Although what you say in the interview is confidential, should you disclose anything to us which we feel puts you or anyone else at any risk, we may feel it necessary to report this to the appropriate persons.

What will happen to the results of the research study?

The results of the study will be used in writing up doctoral thesis which will later on be published. It is possible that the data will also be used in other scientific publications, such as academic articles and journals, but your identity will be anonymized, and you will be notified.

Who is organising and funding the research?

This research is being organised by the University of Nottingham and is being funded by the Faculty of Engineering Research Excellence PhD Scholarship

Who has reviewed the study?

All research in the University of Nottingham is looked at by a group of people, called a Research Ethics Committee, to protect your interests. This study has been reviewed and approved by the School of Engineering Research Ethics Committee.

Further information and contact details

Researcher: Ahmed Ehab Abdelsalam, ezxaa32@exmail.nottingham.ac.uk

Supervisor/PI: Pr. Tim Heath, lazth@exmail.nottingham.ac.uk

Research Ethics Officer: Dr Alison Mohr, alison.mohr@nottingham.ac.uk

2020-21 academic year only

Faculty of Engineering
Application for approval of research study involving human participants

ALL applicants must provide the following information

The applicant must be the person who will conduct the investigations; each application must be made by one applicant:

- usually the student in the case of taught or research courses,
- usually the researcher (the member of university research or academic staff) who will conduct the study in the case of funded research projects,
- usually the principal investigator in the case of applications for ethics approval in advance of submission of a research proposal

If the applicant is an Undergraduate or Postgraduate taught or research student please complete the information below. The application must be approved by a Supervisor.

Name of student:	Ahmed Ehab Abdelsalam	Student No:	20090457
Course of study:	PhD Architecture (Science)	Email address:	Ahmed.Abdelsalam@nottingham.ac.uk
Supervisor:	Prof. Tim Heath	PGR ■	PGT □
		UG □	

If the applicant is a member of university research or academic staff, please complete the information below:
For research staff, the application must be approved by the Principal Investigator

Name:		Principal Investigator (Budget Holder)	
Email address:		PI Signature:	

Title of investigation: Sustainable Vertical Urbanism - design and practice of vertical social spaces in coexistence with COVID 19 situation (Direct observation study & Semi structured interviews).

Planned date for study to begin once the ethical application form and supporting documents have been reviewed and approved (23 June 2021) Duration of Study 10 days

Please state whether this application is:

■ New □ Revised □ A renewal □ For a continuation study

Selection of review process

Please indicate whether the application is required to go forward to the ethics committee for formal review, or, in the case of projects completed by ***taught undergraduate and postgraduate students only***, whether the application can be approved by the supervisor under the expedited review process*.

■ Formal review, application will be submitted to ethics committee

□ Expedited review, application is approved by supervisor*
* This option can only be selected if the Supervisor is a member of the Faculty Ethics committee

2020-21 academic year only

Ethical Issues Checklist

The purpose of this Checklist is to facilitate the review process and to identify any ethical issues that may concern the Committee. It is meant to be an aid to both the researcher and the Committee. Listed below are areas which require some justification and attention on your part in specifying your study protocol. Please answer each question honestly, giving full details where required. Answering "YES" to any of the questions will not necessarily lead to a negative response to your application but it will draw issues to your attention and give the reviewers the opportunity to ensure appropriate steps are being taken. In expedited review, supervisors should ensure that for any questions where the answer "YES" has been given, appropriate measures have been taken to maintain ethical compliance.

Applicant's full name: Ahmed Ehab Abdelsalam

You must complete ALL of this section before submitting your application

1 Who is the population to be studied?

Visitors of London's Sky Garden and Crossrail Place Roof Garden located in Canary Wharf.

2 Please give details of how the participants will be identified, approached and recruited. (Include any relationship between the investigator and participants e.g. instructor-student).

- Participants will be the visitors of the space and they will be invited during the site observation study. Participants will be selected according to various age and user groups. Duration of the observation study is estimated around 3 hours per visit.

- During the study 60 semi-structured interviews will be conducted. The participants will be all aged 18 and above and will be selected. The duration of the interviews is estimated around 10 minutes and participants will be recruited in both spaces.

- Before the interview, interviewees will be given the information sheet including the interview questions, and consent form.
  1. The interviews will be conducted once the potential interviewees have approved and signed the consent form.
  2. The interviews will be conducted in person.

- Participants will not be paid for participation and the observation study will collect no information to reach the participant in any way.

3 Will the population studied include any vulnerable members of the public? Note: for the purpose of ethics approval this includes participants who are under 18, people who are disabled or in poor health, and also those who are non-English speakers and may not be able to understand the consent forms. (If YES, please give further details)

YES	NO
☐	■

Information will not be accessed or used by anyone else apart from the researcher and supervisor.

4 Will it be possible to associate specific information in your records with specific participants on the basis of name, position or other identifying information contained in your records?

YES	NO
☐	■

5 What steps have you taken to ensure confidentiality of personal information and anonymity of data both during the study and in the release of its findings?

- This research will be following the Data Protection Act 1998 (UK) and GDPR. .
- Information will not be accessed or used by anyone else apart from the researcher and supervisor.

The interviewees will be given the options in the consent form if they want their personal information to be identified or not.

At the end of a student project, students are responsible for ensuring that all data from the study is passed on to their academic supervisor/s. The supervisors/s will then have responsibility for the storage of that data.

- During the research, all data will be stored in a password protected filed and stored in a locked filing cabinet and scanned to be stored digitally on a password protected external hard drive. The researcher and supervisor will be the only person with access to the raw data.
- In accordance with the Data Protection Act and the rule of the University of Nottingham, the data will be kept securely for seven years following publication of results. After this time, electronic files will be deleted, and any hard copies will be destroyed.

		YES	NO
7	Will persons participating in the study be subjected to physical or psychological discomfort, pain or aversive stimuli which is more than expected from everyday life? (If YES, please give further details)	☐	■
8	Will participants engage in strenuous or unaccustomed physical activity? (If YES, please give further details)	☐	■
9	Will the investigation use procedures designed to induce participants to act contrary to their wishes? (If YES, please give further details)	☐	■
10	Will the investigation use procedures designed to induce embarrassment, humiliation, lowered self esteem, guilt, conflict, anger, discouragement or other emotional reactions? (If YES, please give further details)	☐	■
11	Will participants be induced to disclose information of an intimate or otherwise sensitive nature? (If YES, please give further details)	☐	■
12	Will participants be deceived or actively misled in any manner? (If YES, please give further details)	☐	■
13	Will information be withheld from participants that they might reasonably expect to receive? (If YES, please give further details)	☐	■
14	Will the research involve potentially sensitive topics? (If YES, please give further details)	☐	■
15	Will data be collected which requires potentially invasive procedures (eg attaching electrodes to the skin) and/or other health-related information to be identified (eg heart rate). If yes please give details	☐	■

2020-21 academic year only

Checklist of information to include with your application:
Please tick the boxes below to confirm that you have included the following information with your submission. Failure to include the required information may result in your ethics application and approval for start of your research to be delayed.

- ■ A brief description of the study design:
  - number and type of participants
  - number and duration of activities participants will be involved in
  - equipment and procedures to be applied
  - information about how participants will be recruited
  - whether participants will be paid (state how this will be done)
  - plans to ensure participant confidentiality and anonymity
  - plans for storage and handling of data
  - information about what will happen to the data after the study
  - information about how any data and images may be used
  - state whether it will be possible to identify any individuals.

- ■ Copies of any information sheets to be given to participants (include recruitment information (e.g. adverts, posters, letters, etc)

- ■ A copy of the participant consent form

- ■ Copies of data collection sheets, questionnaires, etc

I confirm that all of the above is included in the application:

As the applicant I confirm that I have read and understand the Ethical requirements for my study and have read and complied with the University of Nottingham Code of Research Conduct and Research Ethics.

Signature of applicant Ahmed Ehab Abdelsalam Date 31/05/2021

As supervisor, I confirm that I have checked the details of this application.

Signature of supervisor Date 31/05/2021

Ethics Committee Reviewer Decision

This form must be completed by each reviewer. Each application will be reviewed by two members of the ethics committee. Reviews may be completed electronically and sent to the Faculty ethics administrator from a University of Nottingham email address, or may be completed in paper form and delivered to the Faculty of Engineering Research Office.

Applicant full name Ahmed Abdelsalam

Reviewed by:

Name M03

Signature (paper based only) ....

Date 07/06/2021

- [x] Approval awarded - no changes required
- [ ] Approval awarded - subject to required changes (see comments below)
- [ ] Approval pending - further information & resubmission required (see comments)
- [ ] Approval declined – reasons given below

Comments:

Please note:

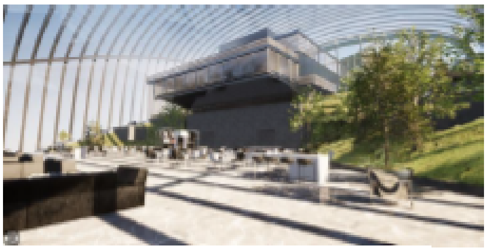
1. The approval only covers the participants and trials specified on the form and further approval must be requested for any repetition or extension to the investigation.
2. The approval covers the ethical requirements for the techniques and procedures described in the protocol but does not replace a safety or risk assessment.
3. Approval is not intended to convey any judgement on the quality of the research, experimental design or techniques.
4. Normally, all queries raised by reviewers should be addressed. In the case of conflicting or incomplete views, the ethics committee chair will review the comments and relay these to the applicant via email. All email correspondence related to the application must be copied to the Faculty research ethics administrator.

Any problems which arise during the course of the investigation must be reported to the Faculty Research Ethics Committee

Appendix B: Virtual Experience Immersive Study

5D Interactive Design Experience- design and practice of vertical social spaces in coexistence with COVID 19 situation

Name of Researcher: Ahmed Ehab   Supervisors: Prof. Tim Heath, Prof. Gary Burnett



VR 3D model for London Sky Garden

VR 3D model for Crossrail Place Roof Garden

Call for Participants!!

We would like to invite you to take part in our research study. The purpose of this study is to co-create a new participation design model for designing vertical green social spaces. This methodology brings the participant as an active element of the project, able to preview the space, propose changes and be part of what later on will be a liveable and safe space.

The study aims to test a new interactive design approach for wellbeing and social resilience following the COVID -19 pandemic. The study will investigate how technologies such as VR can enhance the design experience of vertical green spaces and enable community engagement.

The VR exploratory experiment will last around one hour, participants will have the opportunity to interact with the VR model of London Sky Garden and Crossrail Place Roof Garden. The VR model will allow participants to see in an immersive way the changes and actions that happen in the environment in real-time. During the experiment, participants will have to explore the space, navigate around, change materials, move objects and take virtual photos. By the end of the VR experiment semi-structured interviews will be conducted to explore the virtual experience of the participants behaviour and their interaction with the design.

All participants must be over the age of 18. Participants that can take part in the study should not suffer from motion sickness, dizziness, eye disorder and any conditions that are likely to be exacerbated by use of a headset. The study has been approved by the University of Nottingham Faculty of Engineering Ethics committee and conforms with all relevant COVID-19 safe working practices.

Participants will not be paid an allowance to participate in the study but as a token of thanks you will be given a £10 One4all gift card.

The study should take around 1.5 hours. If you are interested in participating please email Ahmed Ehab on ezxaa32@exmail.nottingham.ac.uk.

Participant Consent Form

Name of Study: 5D Interactive Design Experience

Name of Researcher: Ahmed Ehab Abdelsalam   Student ID: 20090457

Name of Participant:

By signing this form, I confirm that (please initial the appropriate boxes):	**Initials**
I have read and understood the Participant Information Sheet, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study up until one month after the interview took place, without having to give a reason.	
Taking part in this study involves an interview and observations (VR experiment) of the participant that will be video recorded. Video and audio recordings will be transcribed, and recordings destroyed.	
Personal information collected about me that can identify me, such as my name or where I live, will not be shared beyond the study team.	
My words can be quoted in publications, reports, web pages and other research outputs.	
I give permission for the de-identified (anonymised) data that I provide to be used for future research and learning.	
I agree to follow the health and safety guidance for research involving face-to-face participation during Covid-19 restrictions	

I agree to take part in the study

______________________ ______________________ ________________

Name of Participant Signature Date

______________________ ______________________ ________________

Researcher's name Signature Date

Privacy information for Research Participants

For information about the University's obligations with respect to your data, who you can get in touch with and your rights as a data subject, please visit: https://www.nottingham.ac.uk/utilities/privacy.aspx.

Why we collect your personal data

We collect personal data under the terms of the University's Royal Charter in our capacity as a teaching and research body to advance education and learning. Specific purposes for data collection on this occasion are writing up a PhD thesis which is a necessary condition of finishing a PhD degree.

Legal basis for processing your personal data under GDPR

The legal basis for processing your personal data on this occasion is Article 6(1a) consent of the data subject.

Special category personal data

In addition to the legal basis for processing your personal data, the University must meet a further basis when processing any special category data, including: personal data revealing racial or ethnic origin, political opinions, religious or philosophical beliefs, or trade union membership, and the processing of genetic data, biometric data for the purpose of uniquely identifying a natural person, data concerning health or data concerning a natural person's sex life or sexual orientation.

The basis for processing your sensitive personal data on this occasion is Article 9(2a) the data subject has given explicit consent to the processing, OR Article 9(2e) processing relates to personal data which are manifestly made public by the data subject, OR Article 9(2j) processing is necessary for archiving purposes in the public interest, scientific or historical research purposes.

How long we keep your data

The University may store your data for up to 25 years and for a period of no less than 7 years after the research project finishes. The researchers who gathered or processed the data may also store the data indefinitely and reuse it in future research. Measures to safeguard your stored data include pseudonymisation procedure and anonymisation of data.

Who we share your data with

Extracts of your data may be disclosed in published works that are posted online for use by the scientific community. Your data may also be stored indefinitely on external data repositories (e.g., the UK Data Archive) and be further processed for archiving purposes in the public interest, or for historical, scientific or statistical purposes. It may also move with the researcher who collected your data to another institution in the future.

Personal Comfort checklist (to be completed before and after study/experimental conditions)

Please read the following list of symptoms carefully and consider the scale provided. Please rate on the scale with a cross how you would rate your current feelings of each symptom.

Symptoms:

Headache	0 1 2 3 4 5 6 7 8 9 10 No symptom at all — Unbearable level of symptom
Eyestrain	0 1 2 3 4 5 6 7 8 9 10 No symptom at all — Unbearable level of symptom
Blurred vision	0 1 2 3 4 5 6 7 8 9 10 No symptom at all — Unbearable level of symptom
Dizziness	0 1 2 3 4 5 6 7 8 9 10 No symptom at all — Unbearable level of symptom
Sickness	0 1 2 3 4 5 6 7 8 9 10 No symptom at all — Unbearable level of symptom

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Participant Information Sheet

Date: 16/3/2022

Title of Study: 5D Interactive Design Experience- design and practice of vertical social spaces in coexistence with COVID 19 situation

Name of Researcher: Ahmed Ehab   Supervisors: Prof. Tim Heath, Prof. Gary Burnett

We would like to invite you to take part in our research study. Before you decide we would like you to understand why the research is being done and what it would involve for you. One of our team will go through the information sheet with you and answer any questions you have. Talk to others about the study if you wish. Ask us if there is anything that is not clear.

Participation in this study is entirely voluntary and you can withdraw at any point and without giving a reason.

Health warnings:

Participants that can take part in the study should not suffer from motion sickness, dizziness, eye disorder and any conditions that are likely to be exacerbated by use of a headset.

What is the purpose of the study?

The purpose of this study is to co-create a new participation design model for designing vertical green social spaces. This methodology brings the participant as an active element of the project, able to preview the space, propose changes and be part of what later on will be a liveable and safe space.

The study aims to test a new interactive design approach for wellbeing and social resilience following the COVID -19 pandemic. The study will investigate how technologies such as VR can enhance the design experience of vertical green spaces and enable community engagement.

Why have I been invited?

You are being invited to take part as the study aims to target 33 participants from different age groups and different fields as member of staff, students, architects and urban designers. Participants aged above 18 could participate in the study by signing an online consent form in compliance the ethics statement and privacy protection regulations (GDPR, 2016).

Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part, you are still free to withdraw at any time and without giving a reason. This would not affect your legal rights.

What will happen to me if I take part?

Participants who agreed to participate in the experiment will sign a consent form and provide their demographic information. Participants will be asked for a suitable date and time to complete the study. Participants attending the lab will be asked to follow Covid-19 safe procedures and confirmtheir fitness to participate.

The experiment will be divided in to three stages: (1) short presentation and induction that will take around 15 minutes; (2) before the experiments participants needs to fill an initial survey in which they will be asked to answer some questions regarding their previous experience in using VR.; (3) Participants will test the VR model and explore the space for 30 minutes. During the 30 minutes, participants will have 10 minutes break in between.

By the end of the VR experiment, I will conduct short semi structured interviews; to explore the virtual experience of the participants behaviour and their interaction with the design. The interview will discuss (I) the design quality of the space such as (accessibility, circulation, activities, design features and social distancing), (II)the participants virtual experience and behaviour during the study, (III) the study impacts on physical and mental wellbeing, and (IV) the effectiveness of the design used tools. The duration of the interview is estimated to take around 30 minutes and the conversations will be recorded and transcribed, after which the recordings will be deleted.

You will be asked if you are happy to be video recorded/have photographs taken to be used for the research observation analysis and in promotional/informational material for the project. You will not be put under pressure to agree to this, if you are happy for us to record you/take photographs please indicate this in the consent form.

Expenses and payments

Participants will not be paid an allowance to participate in the study but as a token of thanks you will be given a £10 One4all gift card.

What are the possible benefits of taking part?

We cannot promise the study will help you but the information we get from this study may improve the design of vertical social space, help experts to develop new suggested solutions for creating vertical social spaces that feel safe, operate effectively, and add value for users and developers and also address common challenges and community issues such as accessibility, circulation, activities, limitations of visitors, social distancing.

What are the possible disadvantages and risks of taking part?

Exposure to virtual reality can disrupt the sensory system and lead to symptoms such as nausea, dizziness, sweating, pallor, loss of balance, etc., which are grouped together under the term "virtual reality sickness". In sensitive individuals, these symptoms may appear within the first few minutes of use. If participants feel discomfort, they can withdraw at any point and without giving a reason.

<u>COVID Safety:</u>

The study will follow the health and safety guidance for research involving face-to-face participation during Covid-19 restrictions.

1. The participants and the researcher will be required to wear a face mask during the study and respect the social distancing guidance.
2. After each use, the headset will be sanitised using the Human Factors Research Group antibacterial lightbox for 'cleaning' the VR headsets. This will include the interior and exterior of the headset and the controllers.
3. A hand sanitiser will be available to wash hands immediately before and after the experiment.
4. Good ventilation for the room that ensures the regular exchange of fresh air creates a healthier environment.
   - Opening windows and/or air vents, where present, to provide a fresh air supply.
   - Opening doors in combination with windows to encourage through-draughts wherever practical.

What if there is a problem?

If you have a concern about any aspect of this study, you should contact me, and I will do my best to answer your questions. If you remain unhappy and wish to complain formally, you can do this by contacting the School Research Ethics Officer. All contact details are given at the end of this information sheet.

What will happen if I don't want to carry on with the study?

Your participation is voluntary, and you are free to withdraw at any time, without giving any reason, and without your legal rights being affected.

Will my taking part in the study be kept confidential?

We will follow ethical and legal practice and all information about you will be handled in confidence.

If you join the study, the data collected for the study will be looked at by authorised persons from the University of Nottingham who are organising the research. They may also be looked at by authorised people to check that the study is being carried out correctly. All will have a duty of confidentiality to you as a research participant and we will do our best to meet this duty.

All information which is collected about you during the course of the research will be kept strictly confidential, stored in a secure and locked office, and on a password protected database. Any information about you which leaves the University will have your name and address removed (anonymised) and a unique code will be used so that you cannot be recognised from it. Anonymised data may also be stored in data archives for future researchers interested in this area.

Your personal data will be kept for 1 year after the end of the study so that we are able to contact you about the findings of the study and possible follow-up studies (unless you advise us that you do not wish to be contacted). All research data will be kept securely for 7 years. After this time your data will be disposed of securely. During this time all precautions will be taken by all those involved to maintain your confidentiality, only members of the research team will have access to your personal data.

Although what you say in the interview is confidential, should you disclose anything to us which we feel puts you or anyone else at any risk, we may feel it necessary to report this to the appropriate persons.

What will happen to the results of the research study?

The results of the study will be used in writing up doctoral thesis which will later on be published. It is possible that the data will also be used in other scientific publications, such as academic articles and journals, but your identity will be anonymized, and you will be notified.

Who is organising and funding the research?

This research is being organised by the University of Nottingham and is being funded by the Faculty of Engineering Research Excellence PhD Scholarship

Who has reviewed the study?

All research in the University of Nottingham is looked at by a group of people, called a Research Ethics Committee, to protect your interests. This study has been reviewed and approved by the School of Engineering Research Ethics Committee.

Further information and contact details

Researcher: Ahmed Ehab Abdelsalam, ezxaa32@exmail.nottingham.ac.uk

Supervisor/PI: Prof. Tim Heath, lazth@exmail.nottingham.ac.uk

Prof. Gary Burnett, gary.burnett@nottingham.ac.uk

Research Ethics Officer: Dr Ed Morris, david.morris@nottingham.ac.uk

5D Interactive Design Experience

Study outline

The main aim of this study is to co-create a new participation design model for designing vertical green social spaces. This methodology brings the participant as an active element of the project, able to preview the space, propose changes and be part of what later on will be a liveable and safe space. The study uses a mixed method approach which is divided in to two parts. The first method will be aVR exploratory experiment, followed by semi-structured interviews with the participants.

VR Experiment

(60 minutes)

1- Introductory presentation about the research and the experiment.
2- Participants filling research questionnaire demographic information.
3- Participants testing the VR model, walking in the space, changing materials, moving objects and taking virtual photos.

→

Semi structured interviews

(30 minutes)

The interviews structured will cover:

1. The design quality of the space such as (accessibility, circulation, activities, design features and social distancing).
2. Participants virtual experience and behaviour.
3. The study impacts on physical and mental wellbeing.
4. The effectiveness of the design used tools.

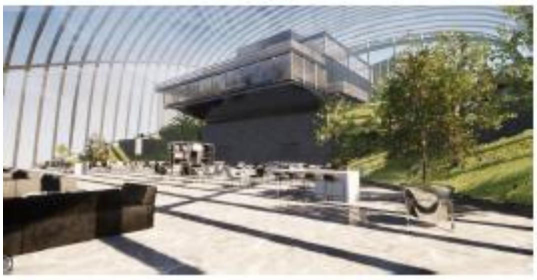

Figure.1. VR 3D model for London Sky Garden

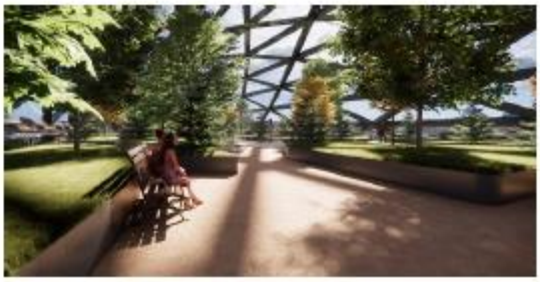

Figure.2. VR 3D model for Crossrail Place Roof

1- VR Experiment as an observation study

The Virtual Reality (VR) experiment aims to test a new interactive design approach for wellbeing and social resilience following the COVID -19 pandemic. The study will investigate how technologies such as VR can enhance the design experience of vertical green spaces and enable community engagement.

1.1 Objectives

- To explore people behaviour and their interaction with the design phase and, to observe how public are perceiving the space in terms of circulation, social distancing and activities.
- To examine the study impacts on physical and mental wellbeing.

1.2 Participants

The study aims to target 33 participants from different age groups and different fields as architects, urban designers, and public living in England. Participants that can take part in the study should not suffer from motion sickness, dizziness, eye disorder and any conditions that are likely to be exacerbated by use of a headset. Participants aged above 18 could participate in the studyby signing an online consent form in compliance the ethics statement and privacy protection regulations (GDPR, 2016).

Participants will be recruited using snowball sampling via various international networks. Participants will be invited through an email, which will include detailed information on the study. In order to maximise the generalisation of the result and to ensure that the findings are representative, a very targeted sampling methods will be used (I) to ensure that participants come from various parts across the architecture and urban design sectors (large and small architecture firms), (II) academics and experts in the discussed topic are invited to obtain different perspective in the subject, and (III) public users from different age group and gender.

Participants classifications

Group A	Previously visited the Sky Garden	Haven't been to the Sky Garden before
Group B	Experts in the field • Architects • Urban Designers • Interior designers • Academics	Public and Students
Group C	Used VR before	First time using VR

1.3 Environment and equipment

The VR exploratory experiment will last around one hour, participants will have the opportunity to interact with the VR model of London Sky Garden and Crossrail Place Roof Garden. The VR model will allow participants to see in an immersive way the changes and actions that happen in the environment in real-time. During the experiment, participants will have to explore the space, navigate around, change materials, move objects and take virtual photos.

The study will use Oculus Quest 2 which is a standalone virtual reality headset created by Facebook Technologies, a division of Meta. The Quest 2 uses four built-in cameras to track the real environment. The headset is able to track full six degrees of movement while users moving around in the virtual environment.

The Blueprint Visual Scripting system in Unreal Engine is a complete gameplay scripting system based on the concept of using a node-based interface to create gameplay elements from within Unreal Editor.

1.4 Health and safety:

Exposure to virtual reality can disrupt the sensory system and lead to symptoms such as nausea, dizziness, sweating, pallor, loss of balance, etc., which are grouped together under the term "virtual reality sickness". In sensitive individuals, these symptoms may appear within the first few minutes of use. If participants feel discomfort, they can withdraw at any point and without giving a reason.

Locomotion method (joystick teleportation) is considered one of the main obstacles to achieve the best results for the VR experience, as many of the participants might lose the sense of the space and they could experience motion sickness. VR motion sickness happens when your eyes tell your brain you're moving around in a VR environment, but your body feels like it's sitting in a chair or standing still. Participants will use a new teleportation system that will allow the participants to physically movein the virtual space.

Actions taken to reduce risks of discomfort and VR-induced sickness

1. During the induction session the participants will watch the researcher trying the experience first before they try it themselves – this can help users become more comfortable and help establish that the experience is virtual and not real.

2. Introduce experiences gradually by limiting the time the user is exposed to 20 minutes and allowing breaks during this time.

Activity	Duration
VR Sickness Questionnaire	5 minutes
London Sky Garden (VR experiment)	10 minutes
Break (VR Sickness Questionnaire)	10 minutes
Crossrail Place Roof Garden (VR experiment)	10 minutes
Break (VR Sickness Questionnaire)	10 minutes

3. To reduce the risk of discomfort, the researcher will adjust the viewing focus for each user before the use of the headset.

4. Good ventilation for the room that ensures the regular exchange of fresh air.

5. Participants will have the option to wear anti-nausea travel sickness wristband during the study. The wristband provides relief from nausea and motion sickness and has no side effects.

6. The study will use a new teleportation system that will encourage the participants to walk in the physical space. The new teleportation method will help to reduce the motion sickness side effects and it will also allow the participants to move freely and explore the space.

7. The researcher will create a safe environment to ensure that there are no immediate obstructions surrounding the user before they put the headset on by setting up a Guardian. Oculus Guardian is a built-in safety feature that enables the participant to set up boundaries in VR that appear when they get too close to the edge of the play area.

    - Stationary: For using the headset while sitting or standing in place. Stationary mode creates a default Guardian area of 1 by 1 metre.
    - Room-scale: For using the headset while moving around inside the play area. Room-scale allows participants to draw the Guardian boundaries in the physical space using the Touch controller. Meta Quest recommends a safe and unobstructed space measuring at least 2 by 2 metres. https://www.youtube.com/watch?v=GojevL05Avw

8. The researcher will enable the Space Sense safety feature that allows the participants to see outlines of people and other objects that cross over the boundaries of the room-scale Guardian while they're in VR. The Space Sense feature can show outlines of objects up to 2.7 metres.

9. The researcher will observe and monitor the participant's reactions whilst they are testing the VR model and encourage them to discuss their experience during and afterwards. During the break sessions, participants should fill in the personal comfort checklist to monitor the participant's feelings about each symptom. If participants feel discomfort, they can withdraw at any point and without giving a reason.

COVID Safety:

The study will follow the health and safety guidance for research involving face-to-face participation during Covid-19 restrictions.

1. The participants and the researcher will be required to wear a face mask during the study and respect the social distancing guidance.
2. After each use, the headset will be sanitised using the Human Factors Research Group antibacterial lightbox for 'cleaning' the VR headsets. This will include the interior and exterior of the headset and the controllers.
3. A hand sanitiser will be available to wash hands immediately before and after the experiment.
4. Good ventilation for the room that ensures the regular exchange of fresh air creates a healthier environment.
   - Opening windows and/or air vents, where present, to provide a fresh air supply.
   - Opening doors in combination with windows to encourage through-draughts wherever practical.

1.5Procedure

Participants who agreed to participate in the experiment will sign a consent form. The experiment will be divided in to three stages: (1) short presentation and induction that will take around 15 minutes; (2) before the experiments participants needs to fill an initial survey in which they will be asked to answer some questions regarding their previous experience in using VR and visiting the Sky Garden. (3) Participants will test the VR model and explore the space for 20 minutes.

Activity	Duration
Induction (health and safety)	15 minutes
Survey	10 minutes
Sickness Questionnaire	5 minutes
London Sky Garden (VR experiment)	10 minutes
Break (Sickness Questionnaire)	10 minutes
Crossrail Place Roof Garden (VR experiment)	10 minutes
Break (Sickness Questionnaire)	10 minutes
Semi-Structured Interview	30 minutes

2- Semi structured interviews

By the end of the VR experiment semi-structured interviews will be conducted to explore the virtual experience of the participants behaviour and their interaction with the design. The interview will discuss (I) the design quality of the space such as (accessibility, circulation, activities, design features and social distancing), (II)the participants virtual experience and behaviour during the study, (III) the study impacts on physical and mental wellbeing, and (IV) the effectiveness of the design used tools. These interviews will be embedded within a holistic qualitative grounded theory methodology, which is used to establish a novel theory grounded within participants' data and avoids the influences of pre-established theories from the physical study analysis.

The duration of the interview is estimated to take around 30 minutes and the conversations will be recorded and transcribed, after which the recordings will be deleted. During the research, all data will be stored in a password-protected file and stored in a locked filing cabinet and scanned to be stored digitally on a password-protected external hard drive. The researcher and supervisors will be the only person with access to the raw data.

2.1 Semi- structured Interviews Questions

Location: Date: Time: Participant's details (Gender, Age Group): *The participants may not give their personal details at their absolute discretion*

1- How did you feel during the study?

2- Have you experience any side effects during the study?

3- Have you experience VR before?

if yes,

- How was your previous experience compared to today's experience?
- Which field or platform (Gaming, education, film industry)?

If no,

- What is the specific reason behind?

4- Have you been to London's Sky Garden or Crossrail Place Roof Garden before?

If yes,

- How often do you visit the space?
- How long do you usually stay?

5- How do you find the space circulation?

6- What kind of activities would you like to do in the space?

7- Do you have any concerns about the space design that you want to change?

If yes,

- Please indicate your concerns or design obstacles.

8- Would you like to add any other activities or design features?

If yes,

- What are the suggested activities?
- What are the suggested design features?

9- How would you describe your Virtual experience?

10- Do you think VR could have a positive or negative impact on your physical and mental wellbeing & why?

11- Which model do you prefer London Sky Garden or Crossrail Place Roof Garden and why?

12- Which teleportation method do you prefer and why?

13- Which of these interactive design features (light simulation, changing materials, X-Ray, virtual camera, annotations) do you think could improve the design experience and why?

14- What suggestions could improve your virtual experience?

15- Do you think using VR in architecture and urban design could improve the design qualityof the space and why?

16- Do you think VR could be an effective design tool to use for communication and to understand the people actual use for the space and why?

17- What are the main challenges and gaps for using VR in architecture and urban design?

5D Interactive Design Experience

The purpose of this study is to co-create a new participation design model for designing vertical green social spaces. This methodology brings the participant as an active element of the project, able to preview the space, propose changes and be part of what later on will be a liveable and safe space.

The study aims to test a new interactive design approach for wellbeing and social resilience following the COVID -19 pandemic. The study will investigate how technologies such as VR can enhance the design experience of vertical green spaces and enable community engagement.

* Required

* This form will record your name, please fill your name.

Further information and contact details.

In case of any special information or curiosity about the theme, feel free to contact the research project team.
Researcher: Ahmed Ehab Abdelsalam, ahmed.abdelsalam@nottingham.ac.uk (mailto:ahmed.abdelsalam@nottingham.ac.uk)
Supervisor: Prof.Tim Heath, tim.heath@nottingham.ac.uk (mailto:tim.heath@nottingham.ac.uk)

1. Participation in the survey is entirely voluntary and you can withdraw at any point in the survey.

   ◯ I agree

2. By taking part in the survey, you declare that the information shared is entirely yours and will not hold any identifiable information of another individual or individuals.

   ◯ I agree

3. The data collected in this survey will be used for anonymous statistical analysis and, eventually, for publication in international conferences and academic journals. The use of the information provided may include editing, duplication, and incorporation in other works such as posters, papers, conference presentation and websites. The information collected in this survey will not be used for commercial purposes. The data collected will be stored in a secure location in accordance with University of Nottingham regulations, including the General Data Protection Regulation (GDPR).

   ◯ I agree

Survey Questions:

4. Name:

5. Age Group *

- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65 and above

6. Occupation *

- Academic
- Student
- Architect
- Urban Designer
- Interior Designer
- Other

7. State your job title and area of speciality ? *

8. Are you living in? *

- ◯ House
- ◯ Flat or apartment in a Midrise Building
- ◯ Studio
- ◯ Flat in a High-rise Building
- ◯ Student Accommodation
- ◯ Other

9. Do you have access where you live to social spaces? *

- ◯ I have access to private garden
- ◯ I have access to roof garden
- ◯ I have access to Common Room
- ◯ Sky Court
- ◯ I don't have access to social space
- ◯ Other

10. Have you been to London Sky Garden before ? *

- ◯ Yes
- ◯ No

11. If yes, how many times have you been there?

12. What are your main concerns about visiting the Sky Garden? *

	Low	Moderate	High
Accessibility	◯	◯	◯
Fear of Heights	◯	◯	◯
Management & Privatisation Regulations	◯	◯	◯
Circulation	◯	◯	◯
Security	◯	◯	◯
Activities	◯	◯	◯
Pre-Booking	◯	◯	◯
COVID Rules	◯	◯	◯
Thermal Comfort	◯	◯	◯

13. Have you been to Crossrail Place Roof Garden, Canary Wharf before ? *

◯ Yes

◯ No

14. If yes, how many times have you been there?

15. What are your main concerns about visiting the Crossrail Place Roof Garden?

	Low	Moderate	High
Accessibility	◯	◯	◯
Management & Privatisation Regulations	◯	◯	◯
Circulation	◯	◯	◯
Activities	◯	◯	◯
Security	◯	◯	◯
COVID Rules	◯	◯	◯
Thermal Comfort	◯	◯	◯

16. Have you used Virtual reality (VR) before ? *

◯ Never

◯ Occasionally

◯ Regularly

17. If yes, which field have used VR before ?

- ☐ Architecture Design
- ☐ Urban design
- ☐ Interior Design
- ☐ Education
- ☐ Gaming
- ☐ Health and safety
- ☐ Mental Health
- ☐ Product Design
- ☐ Social networking
- ☐ Other

18. If you don't use VR frequently, what are your main concerns about the technology?

"Tick all that apply" *

- ☐ It's too expensive
- ☐ The headsets are uncomfortable
- ☐ I get motion sickness from the VR headsets
- ☐ The experience isn't immersive enough
- ☐ There is not enough content that motivate me to buy a VR headset
- ☐ The technology isn't that good yet
- ☐ I don't like to feel cut off from the real world
- ☐ Other

Faculty of Engineering
Application for approval of research study involving human participants

ALL applicants must provide the following information
The applicant must be the person who will conduct the investigations; each application must be made by one applicant:

- usually the student in the case of taught or research courses,
- usually the researcher (the member of university research or academic staff) who will conduct the study in the case of funded research projects,
- usually the principal investigator in the case of applications for ethics approval in advance of submission of a research proposal

If the applicant is an Undergraduate or Postgraduate taught or research student please complete the information below. The application must be approved by a Supervisor.

Name of student:	Ahmed Ehab Abdelsalam	Student No:	20090457
Course of study:	PhD Architecture (Science)	Email address:	Ahmed.Abdelsalam@nottingham.ac.uk
Supervisor:	Prof. Tim Heath	PGR ☒	PGT ☐
		UG ☐	

If the applicant is a member of university research or academic staff, please complete the information below:
For research staff, the application must be approved by the Principal Investigator

Name:		Principal Investigator (Budget Holder)	
Email address:		PI Signature:	

Title of investigation: Sustainable Vertical Urbanism - design and practice of vertical social spaces in coexistence with COVID 19 situation (Direct observation study & Semi structured interviews).

Planned date for study to begin once the ethical application form and supporting documents have been reviewed and approved (23 June 2021) **Duration of Study** 10 days

Please state whether this application is:

☐ New ☒ Revised ☐ A renewal ☐ For a continuation study

Selection of review process

Please indicate whether the application is required to go forward to the ethics committee for formal review, or, in the case of projects completed by *taught undergraduate and postgraduate students only*, whether the application can be approved by the supervisor under the expedited review process*.

☒ Formal review, application will be submitted to ethics committee

☐ Expedited review, application is approved by supervisor*
* This option can only be selected if the Supervisor is a member of the Faculty Ethics committee

Ethical Issues Checklist

The purpose of this Checklist is to facilitate the review process and to identify any ethical issues that may concern the Committee. It is meant to be an aid to both the researcher and the Committee. Listed below are areas which require sc justification and attention on your part in specifying your study protocol. Please answer each question honestly, giving details where required. Answering "YES" to any of the questions will not necessarily lead to a negative response to you application but it will draw issues to your attention and give the reviewers the opportunity to ensure appropriate steps being taken. In expedited review, supervisors should ensure that for any questions where the answer "YES" has been given, appropriate measures have been taken to maintain ethical compliance.

Applicant's full name: Ahmed Ehab Abdelsalam

You must complete ALL of this section before submitting your application

1 Who is the population to be studied?
The study aims to target 33 participants from different age groups and different fields as architects, urban designers, students and public living in England.

2 Please give details of how the participants will be identified, approached and recruited. (Include any relationship between the investigator and participants e.g. instructor-student).

- Participants aged above 18 could participate in the study by signing an online consent form in compliance the ethics statement and privacy protection regulations (GDPR, 2016).
- Participants will be recruited using snowball sampling via various international networks. Participants will be invited through an email, which will include detailed information on the study.
- In order to maximise the generalisation of the result and to ensure that the findings are representative, a very targeted sampling methods will be used (I) to ensure that participants come from various parts across the architecture and urban design sectors (large and small architecture firms), (II) academics and experts in the discussed topic are invited to obtain different perspective in the subject, and (III) public users from different age group and gender.
- The VR exploratory experiment will last around one hour, participants will have the opportunity to interact with the VR model of London Sky Garden and Crossrail Place Roof Garden. The VR model will allow participants to see in an immersive way the changes and actions that happen in the environment in real-time. During the experiment, participants will have to explore the space, navigate around, change materials, move objects and take virtual photos.
- The experiment will be divided in to three stages: (1) short presentation and induction that will take around 15 minutes; (2) before the experiments participants needs to fill an initial survey in which they will be asked to answer some questions regarding their previous experience in using VR and visiting the Sky Garden. (3) Participants will test the VR model and explore the space for 20 minutes.

Activity	Duration
Induction (health and safety)	15 minutes
Survey	10 minutes
VR Sickness Questionnaire	5 minutes
London Sky Garden (VR experiment)	10 minutes
Break (VR Sickness Questionnaire)	10 minutes
Crossrail Place Roof Garden (VR experiment)	10 minutes
Break (VR Sickness Questionnaire)	10 minutes
Semi-Structured Interview	30 minutes

- By the end of the VR experiment semi-structured interviews will be conducted to explore the virtual experience of the participants behaviour and their interaction with the design.

- The duration of the interview is estimated to take around 30 minutes and the conversations will be recorded and transcribed, after which the recordings will be deleted.

- Before the interview, interviewees will be given the information sheet including the interview questions, and consent form.
  1. The interviews will be conducted once the potential interviewees have approved and signed the consent form.
  2. The interviews will be conducted in person.

- Participants will not be paid an allowance to participate in the study but as a token of thanks you will be given a £10 One4all gift card.

		YES	NO
3	Will the population studied include any vulnerable members of the public? Note: for the purpose of ethics approval this includes participants who are under 18, people who are disabled or in poor health, and also those who are non-English speakers and may not be able to understand the consent forms. (If YES, please give further details)	☐	■
4	Will it be possible to associate specific information in your records with specific participants on the basis of name, position or other identifying information contained in your records?	☐	■

Information will not be accessed or used by anyone else apart from the researcher and supervisor.

5 What steps have you taken to ensure confidentiality of personal information and anonymity of data both during the study and in the release of its findings?

- This research will be following the Data Protection Act 1998 (UK) and GDPR.
- Information will not be accessed or used by anyone else apart from the researcher and supervisor.

6 Describe what data will be stored, where, for what period of time, the measures that will be put in place to ensure security of the data, who will have access to the data, and the method and timing of disposal of the data.

Paper records should be stored in a locked filing cabinet. Digital data should be stored only on a password-protected computer and/or on a secure server. In accordance with the Data Protection Act, the data needs to be kept securely for seven years following publication kept securely for seven years following publication of results. After this time, electronic files will be deleted and any hard copies will be destroyed.

At the end of a student project, students are responsible for ensuring that all data from the study is passed on to their academic supervisor/s. The supervisors/s will then have responsibility for the storage of that data.

- During the research, all data will be stored in a password protected filed and stored in a locked filing cabinet and scanned to be stored digitally on a password protected external hard drive. The researcher and supervisor will be the only person with access to the raw data.
- In accordance with the Data Protection Act and the rule of the University of Nottingham, the data will be kept securely for seven years following publication of results. After this time, electronic files will be deleted, and any hard copies will be destroyed.

7 Will persons participating in the study be subjected to physical or psychological discomfort, pain or aversive stimuli which is more than expected from everyday life? (If YES, please give further details)

YES ■ NO □

Exposure to virtual reality can disrupt the sensory system and lead to symptoms such as nausea, dizziness, sweating, pallor, loss of balance, etc., which are grouped together under the term "virtual reality sickness". In sensitive individuals, these symptoms may appear within the first few minutes of use. If participants feel discomfort, they can withdraw at any point and without giving a reason.

Actions taken to reduce risks of discomfort and VR-induced sickness

1. During the induction session the participants will watch the researcher trying the experience first before they try it themselves – this can help users become more comfortable and help establish that the experience is virtual and not real.

2. Introduce experiences gradually by limiting the time the user is exposed to 20 minutes and allowing breaks during this time.

Activity	Duration
VR Sickness Questionnaire	5 minutes
London Sky Garden (VR experiment)	10 minutes
Break (VR Sickness Questionnaire)	10 minutes
Crossrail Place Roof Garden (VR experiment)	10 minutes
Break (VR Sickness Questionnaire)	10 minutes

3. To reduce the risk of discomfort, the researcher will adjust the viewing focus for each user before the use of the headset.

4. Good ventilation for the room that ensures the regular exchange of fresh air.

5. Participants will have the option to wear anti-nausea travel sickness wristband during the study. The wristband provides relief from nausea and motion sickness and has no side effects.

6. The study will use a new teleportation system that will encourage the participants to walk in the physical space. The new teleportation method will help to reduce the motion sickness side effects and it will also allow the participants to move freely and explore the space.

7. The researcher will create a safe environment to ensure that there are no immediate obstructions surrounding the user before they put the headset on by setting up a Guardian. Oculus Guardian is a built-in safety feature that enables the participant to set up boundaries in VR that appear when they get too close to the edge of the play area.

    - Stationary: For using the headset while sitting or standing in place. Stationary mode creates a default Guardian area of 1 by 1 metre.
    - Room-scale: For using the headset while moving around inside the play area. Room-scale allows participants to draw the Guardian boundaries in the physical space using the Touch controller. Meta Quest recommends a safe and unobstructed space measuring at least 2 by 2 metres. https://www.youtube.com/watch?v=GojevL05Avw

8. The researcher will enable the Space Sense safety feature that allows the participants to see outlines of people and other objects that cross over the boundaries of the room-scale Guardian while they're in VR. The Space Sense feature can show outlines of objects up to 2.7 metres.
9. The researcher will observe and monitor the participant's reactions whilst they are testing the VR model and encourage them to discuss their experience during and afterwards. During the break sessions, participants should fill in the personal comfort checklist to monitor the participant's feelings about each symptom. If participants feel discomfort, they can withdraw at any point and without giving a reason.

10. If the participants feel any symptoms of sickness, they will be asked to rest for 15 minutes and drink fresh water. Participants should stay in the room till they feel better before they are allowed to leave the experiment.

COVID Safety:

The study will follow the health and safety guidance for research involving face-to-face participation during Covid-19 restrictions.

1. The participants and the researcher will be required to wear a face mask during the study and respect the social distancing guidance.

2. After each use, the headset will be sanitised using the Human Factors Research Group antibacterial lightbox for 'cleaning' the VR headsets. This will include the interior and exterior of the headset and the controllers.
3. A hand sanitiser will be available to wash hands immediately before and after the experiment.
4. Good ventilation for the room that ensures the regular exchange of fresh air creates a healthier environment.
   - Opening windows and/or air vents, where present, to provide a fresh air supply.
   - Opening doors in combination with windows to encourage through-draughts wherever practical.

8	Will participants engage in strenuous or unaccustomed physical activity? (If YES, please give further details)	YES ☐	NO ■
9	Will the investigation use procedures designed to induce participants to act contrary to their wishes? (If YES, please give further details)	YES ☐	NO ■
10	Will the investigation use procedures designed to induce embarrassment, humiliation, lowered self esteem, guilt, conflict, anger, discouragement or other emotional reactions? (If YES, please give further details)	YES ☐	NO ■
11	Will participants be induced to disclose information of an intimate or otherwise sensitive nature? (If YES, please give further details)	YES ☐	NO ■
12	Will participants be deceived or actively misled in any manner? (If YES, please give further details)	YES ☐	NO ■
13	Will information be withheld from participants that they might reasonably expect to receive? (If YES, please give further details)	YES ☐	NO ■
14	Will the research involve potentially sensitive topics? (If YES, please give further details)	YES ☐	NO ■
15	Will data be collected which requires potentially invasive procedures (eg attaching electrodes to the skin) and/or other health-related information to be identified (eg heart rate). If yes please give details	YES ☐	NO ■

Checklist of information to include with your application:
Please tick the boxes below to confirm that you have included the following information with your submission. Failure to include the required information may result in your ethics application and approval for start of your research to be delayed.

- ■ A brief description of the study design:
    - number and type of participants
    - number and duration of activities participants will be involved in
    - equipment and procedures to be applied
    - information about how participants will be recruited
    - whether participants will be paid (state how this will be done)
    - plans to ensure participant confidentiality and anonymity
    - plans for storage and handling of data
    - information about what will happen to the data after the study
    - information about how any data and images may be used
    - state whether it will be possible to identify any individuals.
- ■ Copies of any information sheets to be given to participants (include recruitment information (e.g. adverts, posters, letters, etc)
- ■ A copy of the participant consent form
- ■ Copies of data collection sheets, questionnaires, etc

I confirm that all of the above is included in the application:

As the applicant I confirm that I have read and understand the Ethical requirements for my study and have read and complied with the University of Nottingham Code of Research Conduct and Research Ethics.

Signature of applicant Ahmed Ehab Abdelsalam Date 16/03/2022

As supervisor, I confirm that I have checked the details of this application.

Signature of supervisor Date 16/03/2022

NB The signature of the supervisor on this part of the application DOES NOT indicate supervisor approval for expedited review. If supervisor approval is granted then the front page of the application MUST be signed for approval to be confirmed.

Ethics Committee Reviewer Decision

This form must be completed by each reviewer. Each application will be reviewed by two members of the ethics committee. Reviews may be completed electronically and sent to the Faculty ethics administrator (Donna Astill-Shipman) from a University of Nottingham email address, or may be completed in paper form and delivered to the APM Hub

Applicant full name: Ahmed Ehab Abdelsalam
Reviewed by:

Name C8..............................

Signature (paper based only) ....

Date: 21.03.22

- [x] Approval awarded - no changes required
- [ ] Approval awarded - subject to required changes (see comments below)
- [ ] Approval pending - further information & resubmission required (see comments)
- [ ] Approval declined – reasons given below

Comments:

I am happy that the applicant has addressed the comments I originally made.

Please note:

1. The approval only covers the participants and trials specified on the form and further approval must be requested for any repetition or extension to the investigation.
2. The approval covers the ethical requirements for the techniques and procedures described in the protocol but does not replace a safety or risk assessment.
3. Approval is not intended to convey any judgement on the quality of the research, experimental design or techniques.
4. Normally, all queries raised by reviewers should be addressed. In the case of conflicting or incomplete views, the ethics committee chair will review the comments and relay these to the applicant via email. All email correspondence related to the application must be copied to the Faculty research ethics administrator.

Any problems which arise during the course of the investigation must be reported to the Faculty Research Ethics Committee