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Virtual Environments as Medium for Laypeople's Communication and Collaboration in Urban Design

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Abstract

The distance between urban design processes and outcomes and their communication to stakeholders and citizens are often significant. Urban designers use a variety of tools to bridge this gap. Each tool often places high demands on the audience, and each through inherent characteristics and affordances, introduces possible failures to understand the design ideas, thus imposing a divergence between the ideas, their communication and the understandings.

Urban design is a hugely complex activity influenced by numerous factors. The design exploration process may follow established design traditions. In all instances, the medium in which the exploration takes place affects the understanding by laypeople. Design tools are chosen, in part, to facilitate the design process.

Most urban design community engagement does not use Virtual Environments (VE) as a means of communication and participation in the early stage of the design generation. There has been little research on how the use of VE for urban design can engage laypeople as contributors to the design process. It has been suggested that VE instruments can allow laypeople to express, explore and convey their imagination more easily. The very different nature of perceptual understanding of VE and its capability to produce instant 3D artefacts with design actions may allow laypeople to generate meaningful design ideas. An experiment setup has developed to leverage laypeople in authentic design collaboration.

This thesis examines in the context of New Zealand's National Science Challenge 'Building Better Homes, Towns and Cities' the drivers of change that contribute to the shaping of places, development and design of future neighbourhoods. A series of experiments have been conducted in the site of a neighbourhood to investigate the relative effectiveness of immersive VE to facilitate people in collaborative urban design. The findings support the hypothesis that VE with the generation of 3D artefacts enhances design communication for laypeople to design an urban form for their neighbourhood. The thesis concludes by discussing how New Zealand's

future neighbourhoods can be shaped and developed with VE assisted participatory urban design.

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List of Software

Fuzor   Fuzor is a game engine based visualisation tool developed by Kalloc Studios for validation and analysis of a project during construction and design phases.

Grasshopper 3D   Grasshopper is a visual programming language and environment developed by David Rutten at Robert McNeel and Associates, which runs within Rhinoceros 3D computer-aided design application.

Hyve 3D   An immersive 3D virtual environment without any VR headset and trackers. It has unique features to sketch in 3D planes.

Rhino 3D   Rhinoceros is a commercial 3D computer graphics and computer-aided design application software developed by Robert McNeel and Associates.

ShapeDiver   ShapeDiver automatically turns Rhino and Grasshopper files into interactive 3D models accessible worldwide through web browsers.

SketchPad   SketchPad is an "Unity 3D" based immersive 3D modelling interface developed by Daniel Innes in his masters thesis Innes (2018).

SketchUp   Sketchup is a 3D modelling computer program for a wide range of drawing applications in architecture, interior architecture, landscape architecture, civil and mechanical engineering, film and video game design.

Unity 3D   Unity is a cross-platform game engine developed by Unity Technologies.

VRSketch   An extension of SketchUp for virtual reality drawing tools for architects and designers.

Acronyms

2D	Two-dimensional
3D	Three-dimensional
AR	Augmented Reality
BBHTC	Building Better Homes, Towns and Cities
BIM	Building Information Modelling
CAAD	Computer-Aided Architectural Design
CIVE	Collaborative Immersive Virtual Environment
CIM	City Information Modelling
CSCD	Computer Supported Collaborative Design
MSCD	Modality Supported Collaborative Design
ETHZ	Eidgenössische Technische Hochschule Zürich
FOV	Field of View
GIS	Geographic Information System
HCI	Human-Computer Interface
HMDs	Head-Mounted Displays
IVE	Immersive Virtual Environment
IVR	Immersive Virtual Reality
NSC	National Science Challenge
RMA	Resource Management Act
SRA	Strategic Research Area
VE	Virtual Environment
VR	Virtual Reality
VW	Virtual World
WCC	Wellington City Council

Glossary of Terms

3D Artefacts	3D objects that are created in a computer.
Bottom-up	A design approach that is user-oriented where their needs will be the starting point of the design.
Co-design	A design approach attempting to actively involve all stakeholders in the design process.
Cuboids	A 3D solid which has rectangular faces at right angles to each other.
"Designer" A/B	An agent/layperson who creates 3D artefacts those go with functions.
Design Discussion	Focusses on bringing together a diverse group of designers willing to share experiences in a creative way of problem-solving.
Design Process	An approach for breaking down a large project into manageable chunks. The purpose of a design process is to shape and guide your work and thoughts to improve the outcome.
Design Intuition	There is no agreed definition of the term (" The Interaction Design Foundation," 2019). However, here the term refers to a technical system in a specific context of a user goal where the user is able to interact with it effectively by applying knowledge unconsciously.
Hapu	A division of a Maori people or community.
Hui	In Maori, a large social or ceremonial gathering.
Instrument	A tool or implement to do or facilitate work and also a mean to do something, an agency.
IVE Design Experiment	Non-experts are involved in an urban design task with the developed IVE instrument.
Iwi	A Maori community or people.
Layperson	A person without professional or specialized knowledge in a particular subject.

Mixed Reality	Strives to put fully digital objects that are trackable and intractable in the user's environment.
Participant	A participant is a person willingly choose to engage with the virtual experience.
Stakeholder	A person as a citizen who is involved with an organization, society, etc. and therefore has responsibilities towards it and an interest in its success.
Top-down	A design approach that is driven by a person or an organisation. The design will be almost totally influenced by that person's style and taste. On an organisation level such as a government, the design could be driven based on directives.
Urban Form	The three-dimensional shape of the built environment comprises the buildings themselves and the spaces between them.
Virtual Design Engagement	Engaging designers in a design process through the IVE instrument.
Virtual Environment	A space that is virtual and does not has to have any relationship to reality and is an open system.
Virtual Reality	Related to reality yet does not has to be as close as a world. It is a 'copy' or largely related to reality.
Virtual World	A cohesive system that is akin to real-world in a closed space that is akin to our earthly world.

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I am genuinely grateful to my primary supervisor Prof Marc Aurel Schnabel to believe on me and allow me to work with him on the National Science Challenge 'Building Better Homes, Towns and Cities' (NSC-BBHTC) project. His prompt response to every inquiry and his continuous support and guidance not only allow me to conclude this thesis but also the journey with him made me confident for my future life endeavour.

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I wish to acknowledge the developer of 'SketchPad' Daniel Innes for his immersive instrument and programmer William Judd for helping in exploring different other computational interfaces. I wish to give special thanks to research assistant Keegan Davis to support the research organising the events and invite participants, as well as helping me in transcribing the conversation. Acknowledgement is due to the IT-support staff Stewart Milne to provide constant software support. I also acknowledge the contribution of design participants from the Karori Community and the Urban Design group from Wellington City Council.

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Mita to believe in me and support me in every endeavour I took. I also thank my younger sister, Sharna, who always motivates me to do the right works. I love you all.

Chapter 1 Introduction

Participatory design techniques dealing with urban issues have, to date, often used paper-based methods (Al-Kodmany, 2001) and depended on digitally produced images or three-dimensional artefacts (Bannon et al., 2018). The demand for public participation in the urban design decision-making process allows for accountability on the parts of stakeholders (Healey, 1998; Murray et al., 2009). However, the lack of ability to understand the implications of different design decisions and tools in the design process hinders non-experts from actively taking part in the design of the environments they inhabit. Furthermore, conventional urban design processes do not allow laypeople to easily take part in the design ideation and generation stage. So, the research speculates that a Virtual Environment (VE) facilitated instrument enables laypeople to take part actively as designers in the early stage of an urban design process. The research has been framed to accommodate an urban design task in accordance with the designing scope of the VE instrument. The study develops a design discussion platform for non-experts to produce urban forms by employing virtual tools. Traditional urban design tools are not flexible enough to address design changes in the early design stages and have spatial and temporal limits in their capacity to share design ideas. Moreover, they do not allow laypeople to participate in the stages of design iteration. My

research engages laypeople to take part actively in the design imagination and generation of a neighbourhood design in VE. These tools offer a dynamic virtual interactive platform to visualise and produce iterative design ideas. I discovered that engaging community members in this way enabled them to easily work together to create different designs and to collaborate naturally, including on important—perhaps less exciting—design elements such as driveways and fences.

My research found through a survey of an urban design consultation that laypeople prefer to design by imagining their future neighbourhood. In that case, the research engages laypeople to design and obtain their design interests through discussion. The design framework builds on the ability of the computational instruments and the needs of the design problem. The research discusses initial findings and learnings gained from the experiments with the VE instrument. The results of a protocol analysis show that laypeople participate effectively as designers in ideating and generating new urban forms in their neighbourhood. The research concludes with a reflection on the discussion of how non-experts as co-urban designers can use VE instrument to proactively contribute and impact the liveability of their environment.

This thesis examines in the context of New Zealand's National Science Challenge 'Building Better Homes, Towns and Cities' (NSC-BBHTC) contributes to the shaping of places and the development and design of future neighbourhoods. In particular, the research explores how design ideation, generation, and communication of urban design within VE can facilitate participatory processes among laypeople, urban designers, and other stakeholders. As a case study, I have used the suburb Karori in Wellington, New Zealand. The site is an empty lot in Karori Centre used as the basis for generating new design ideas in the VE participatory platform.

1.1 Research Motivation

The thesis forms a part of the NSC-BBHTC (NSC, 2017). Under the title 'Shaping Places Future Neighbourhood'. The Challenge investigates the drivers for liveable and well-designed neighbourhoods, including houses, which benefit their inhabitants. It explores the complex factors involved in

urban design practices in New Zealand and explores how to improve land-use decision making for future urban environments to ensure thriving communities. It seeks collaboration with stakeholders and evaluates real neighbourhoods. The challenge seeks innovative design practice in major New Zealand cities and enhances uptake of innovation across the country regarding improved urban communities. It aims to discover and establish what processes, and what urban design principles and practices, lead to more successful neighbourhoods in the context of New Zealand cities (NSC, 2017). It looks for research that helps transform people's dwellings and neighbourhoods.

The mission of NSC-BBHTC states the importance of "co-created innovative research that helps transform people's dwellings into homes and communities that are hospitable, productive and protective" (NSC, 2017).

One of the 'drivers of changes' considered in NSC-BBHTC is the potentiality of implementing smart technologies in neighbourhood design. The success of future neighbourhoods will be affected by ensuring citizens are empowered to make meaningful contributions to urban design decision-making process and establishing successful stakeholder collaboration during the design process.

One of the research questions across this challenge, which motivated this research is, *"How can digital media be effectively deployed better to communicate innovative design alternatives for neighbourhoods to communities and other stakeholders?" (NSC, 2015)*

An urban design project seeks agreement from multiple stakeholders of cross-disciplinary fields. Sometimes participatory urban design approaches are sidelined as developers see it as a waste of time and money. The design decision prolongation happens due to an individual's background and understanding of the context and their perceptual speculation for the future project. One of the reasons for this conflict arises because of the lack of spatial understanding of their design speculations. Due to a lack of useful instruments, end-users find it difficult to participate in design processes where they can become fully informed by the spatial understanding. It motivates the

study to develop instruments to facilitate end-users to take part in the design process along with other stakeholders.

The continuous evolution of computation in design communication and tools makes it affordable to create inclusive design processes. It facilitates participatory design processes to integrate more democratic voices in design decision making. Such development in communication tools encourages the government to seek design solutions that will be socially, economically, and environmentally sustainable. Participatory urban planning already embraces digital communication tools to leverage laypeople in design decision making. Most of these tools focus on collecting information for site analyses or collect votes on predetermined design ideas. These participatory practices deal with spatial planning, not being fully conceived the space in terms of perceptual understanding. The procedures show maximum participation from the end-users, but the design decision usually takes on the suggestive spatial design ideas, where they cannot design by themselves with continuous instant spatial feedback of their own decisions. Therefore, my research engages end-users in an artificial environment where they design collaboratively and make decisions on urban spaces in their neighbourhoods.

1.2   Problem Statement

The conventional participatory urban design process does not involve stakeholders and citizens taking part in design ideation and generation stages. It denotes a process of dealing with complex issues composed of physical, economic, political, and social attributes. The design techniques dealing with such complex issues require a comprehensive method to involve non-experts in the initial stage of the design process. Most of the design methods used by urban professionals use paper-pencil and physical artefacts and involve top-down approaches, where the scope of involving laypeople in the design process is very limited. The professionals present their initial concepts as some pre-defined views. Though such a design approach seeks a better urban neighbourhood for its users, lack of visual information and tools does not allow them to take part actively in design ideation and generation stages. Also, the professionally directed design processes are cumbersome to address

further details related to the construction and post-occupancy period. This detailed information is necessary for building professionals to understand and to construct, but it does not help laypeople to understand the overall design ideas (Al-Kodmany, 2001). Because laypeople do not know how to interpret the drawing details, they can visualise the design through perspectival drawings, rendered images, or three-dimensional virtual or physical artefacts. However, that state of design re-presentation comes after a long iteration of designers' intervention, where the designers play the major role to guide the design outcome. The non-experts cannot cater to that state of the design generation. On top of that, the design processes lack the ability to offer multiple design ideas instead of one. In fact, it is also impossible for urban professionals to address all of the aspects of urban dynamics in a single design process.

Most urban design community engagement does not use VE as a means of communication and participation. There has been inadequate research on how the use of VE for urban design can involve laypeople as contributors to the design process. It has been suggested that VE instruments can empower laypeople to express, explore, and convey their imagination more easily. For these reasons, the very different nature of perceptual understanding of VE may allow urban designers to design with stakeholders and laypeople. These tools offer a ubiquitous virtual interaction platform to produce and visualise iterative design ideas. There is barely any basic research examining the use of VE to support the acts of design communication and participation. The thesis seeks a useful VE assisted design discussion platform to produce urban form collectively by laypeople in the conceptual stage of the design process.

1.3 Research Question, Objectives, Significance and Scope

This section sets out the research objectives, questions, significance, and scope of the study.

1.3.1 Research objectives

The research objective is to identify how laypeople as designers can generate an urban form within VE by looking at the creation, interpretation, and communication of urban design in a collaborative setting. The methodology suggests a framework to develop VE instruments for laypeople's design communication and participation.

1.3.2 Research questions

One of the research questions across the NSC-BBHTC challenge looks at how digital media can be more effectively deployed to communicate neighbourhood design alternatives to people and stakeholders. The thesis explores the following primary question:

How do VE instruments facilitate design communication for laypeople in an urban design process?

Sub-questions:

1. How do the attributes of VE instruments perceptually afford laypeople in design communication for designing an urban form?
2. How can 3D design artefacts involve laypeople in urban design collaboration?

1.3.3 Research significance

The significance of this work is to involve laypeople as designers into a VE urban design decision-making process. Existing conventional and participatory urban design processes have not tended to offer shared VE design media for non-experts to effectively become designers together with experts in the early stage of the design processes. This is due to the lack of suitable VE design instruments that can provide real-time visual feedback to support design discussion. Design experts use tools to aid their design process and allow for cross-collaboration, but those tools require years of experience and knowledge to operate. Such tools don't offer opportunities for laypeople as first-time users to visualise and generate urban forms. Thus, to incorporate laypeople as designers in an urban design process, it is necessary to develop

the VE instruments that are simple enough and easy enough to pick up without VE expertise. The overall thesis contributes to involving non-experts as designers in designing future neighbourhoods and presents a novel method for stakeholder's design collaboration in VE supported urban design process.

1.3.4 Research scope

In this section, I define the scope of this study. The research scope involves a wide range of understanding of cross-disciplinary fields, including urban design processes and tools, virtual design representations and participation, and virtual instrument development and expert's role (Figure 1).

1.3.4.1 Design Representation

Designers always seek suitable means to construct imagination, express design concepts and turn the concept into visible artefacts (Chan, 2011). Brown (2003) argues that the design representation is coupled with the content of the virtual environment, which involves perceptual experience, and the design generation of 3D artefacts involves immediate manipulation of mental images. My research includes abstract 3D artefacts that represent instant design ideations and generations. The artefacts of the design representation instigate a meaningful urban design discourse between laypeople to generate an urban form. The thesis focuses only on VE methods as compared with other types of design representation like paper-pencil methods, 3D models, or computer-generated images.

1.3.4.2 Urban Design Processes and Tools in Design Ideation

The institutionalised design techniques in a conventional urban design process lack engaging ways to think and communicate design ideas between professionals and laypeople (Forester, 1988; Friedman, 1973). Similarly, the design techniques in participatory approaches that deal with urban issues often use paper-based methods (Al-Kodmany, 2001) and depend on digitally produced images or 3D artefacts (Bannon et al., 2018). These tools have a lack of visual information that prevents non-experts from taking part actively in the design process as they inhabit the environment. Facilitating a

conversation with laypeople in the design process not only informs them about future design but also allows them to be an active part of the design process. The research scope is to involve laypeople as a part of the participatory urban design process where they approach design decisions collaboratively on urban form's shape, size, and function. A VE design setup is used to facilitate such design collaboration.

1.3.4.3   *Urban Design as Designing Urban Form*

The most commonly accepted definition of urban design is dealing with urban form as 3D places for people and perceptual understanding of surrounding buildings (Madanipour, 1997). The meaning of urban form is the physical characteristics include build-up areas and the shape, size, density, and configuration of settlements. The concept differs in scale from regional to urban, neighbourhoods, blocks, and streets. I consider the generation of an urban form as a physical structure with shape, size, and function. The incentive is to include these attributes of an urban form in a design task derived from the suggestions of WCC on the case site of the Karori neighbourhood.

1.3.4.4   *Design Communication in VE*

VE has increased the level of communications between designers and clients (Schnabel & Kvan, 2002, 2003). It is leveraging the designers with a greater potential to perceive 3D understanding of space and volume. Extension of VE to Immersive-VE (IVE) offers the user an active and real-time interaction with the design and therefore, to some extent, ensures a real sense of presence. So in the case of urban design where communication and visualisation is the heart of any urban design system (Smith et al., 1998), a VE assisted design communication can facilitate laypeople to take part actively in design ideation and the generation stage. Therefore, the dissertation discusses the development of the VR instrument and reports effective design communication and participation with the result of protocol analysis.

1.3.4.5   Role of Experts in the VE Design Process

In the study, the expert plays the roles in task setting for designing engagement, evaluating the generated design, and facilitating the design collaboration between laypeople. Developing the instrument for engaging laypeople in urban design removes the constraints of the design and offers easy use of the computation tool. It helps to elaborate representations and enable previously unimaginable designs. To integrate such a tool with the relevant task for laypeople's design collaboration requires an expert's understanding of possible design interaction between computer and human. The VE instrument and its representation of iterative 3D artefacts provide perceptual and technological affordance for laypeople to generate meaningful design outcomes. According to Cipan (2019), to run a participatory design session, one should investigate any cultural or political disconnect between the expert and the end-user. In that case, current advanced technology in design ideation and production have possibilities to make the design generation democratic (Carpo, 2011; Ortega, 2017).

1.3.4.6   Virtual Instrument Development

Designing a communication instrument requires an understanding of the different routes of a user's experiences (Sanders, 2002). The challenges of developing virtual instruments include the understanding of the algorithm of
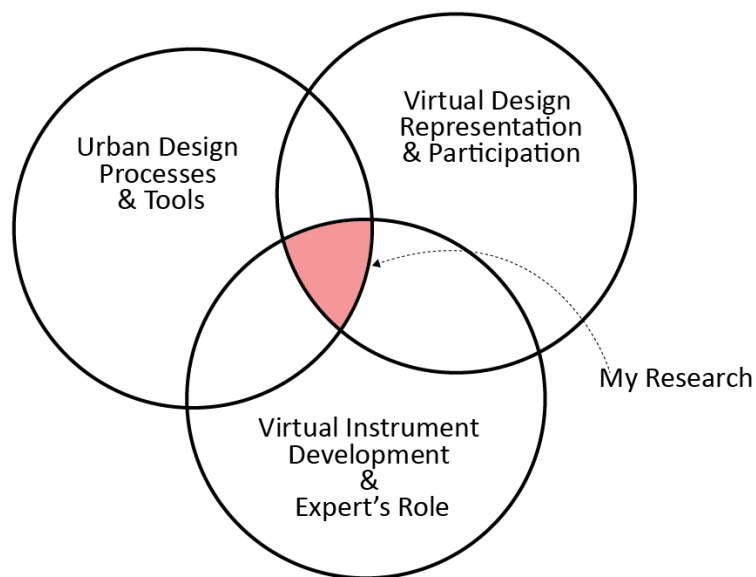
Figure 1 Research scope.*

the systems and sorting out a suitable one that can facilitate the design task - and laypeople's design participation within the research timeframe along with available technical knowledge and resources. Therefore, I intend to find a suitable instrument for the VE experiment.

1.4   Case Study Site

The case study site is Karori, which is a low-density suburb in Wellington, New Zealand (Figure 2). According to New Zealand's urban and infrastructure planning system, to tackle issues related to urbanisation the listed objectives are: 1. drive productivity, 2. enable development, 3. get value for money from infrastructure investment, 4. deliver a quality built environment for an improved quality of life and achieve desired social, cultural, and economic outcomes (Mfe.govt.nz, 2019b). Under this scheme, WCC has cited the Karori Centre to transform to a Medium-density housing area with an improved town centre (Wellington.govt.nz, 2017).

Figure 2 Karori suburb Google map (not in scale).*

In Karori, WCC has run year-long charrettes to understand the community interests and priorities and identify locations for further development (Karori, 2017; Wellington.govt.nz, 2017). To date, the charrette process has generated a map of priorities within the Karori neighbourhood, and the mall area has been signalled as a priority for redevelopment (Karori, 2017). I have conducted a survey during a consultation event arranged by

WCC in the Karori Centre, which is reported in Chapter 7.1 and the results in Chapter 8.1.1. The design task for VE urban design experiment is also based on this suburb, which is described in Chapter 7.3.

1.5   Overview of the Thesis

The thesis hypothesises that immersive virtual 3D modelling facilitates laypeople to take part collaboratively as designers in an urban design process. Table 1 gives an overview of the thesis chapters. In Chapter 1, I introduce the research motivation, scopes, objectives, questions, and overview of the thesis. In Chapters 2 to 5, I discuss a relevant literature review to frame the research problem. The literature review of Chapter 2 covers the concept of design representation, design action, and the expert's role in computer-aided design participation. Chapter 3 discusses the disciplinary ambiguities of urban design, the concept of the participatory design process, the need of mediation in the participatory urban design process, the design communication in urban design processes, and mentions the urban design toolkit for New Zealand. Chapter 4 discusses the concept of VR in design communication and collaboration and puts the focus on the perspective of technological affordances. Next, I discuss some precedents of virtual collaboration in urban planning and design with current references in Chapter 5. Chapter 6 specifies the research methodology. Chapter 7 reports the surveys, the procedure of the instrument development, and the procedure of VE experiment. Then, Chapter 8 reports the results of the survey, analyses the results, and reports on expert evaluation. It also analyses the verbal conversation recorded during the VE experiment through protocol analysis. Finally, in Chapter 9, the thesis discusses the design communication and participation of laypeople in the context of NSC-BBHTC.

Table 1 Overview of the thesis chapters.

Chapter 1 Introduction	Presents the motivation of the research with a problem statement in the context of NSC-BBHTC. It informs the research objectives and questions involving laypeople in a virtual urban design process.

Chapter 2 Design Representation and Expert's Role	Discusses the theoretical concept of design representation, the concept of a design through action and using artefacts to design interpretation, and the expert's role in the computational design process.
Chapter 3 Communication and Participation in Urban Design	Discusses the concept of participatory urban design process, design communication in urban design, the role of design representation and communication in urban spatial design, and urban design toolkits in New Zealand.
Chapter 4 Communication and Visualisation in Virtual Environment	Discusses the concept of virtual reality, its sense of embodiment and interaction in behavioural science, perceptual understanding in IVE, the concept of collaborative design in VE, concept of coding in design communication and protocol analysis, concept of technological affordances, and designing communication tools.
Chapter 5 Precedents	Informs relevant research and tools in participatory virtual urban design and collaborations.
Chapter 6 Research Methodology	Presents a detail description of the methodologies adopted in this thesis.
Chapter 7 Surveys, Instrument Development, Design Experiment, and Design Task	Reports an urban design consultation done by WCC and the questions. It discusses the stages of instrument development, the steps to immersive virtual experiment, the reason behind developing the design task, the description of the virtual design experiment, and the details of VE survey questions.
Chapter 8 Results and Analysis	Reports the outcome of the questionnaire surveys and the protocol analysis of the verbal conversation that occurred during the VE urban design experiment.

Chapter 9 Discussion	Discusses the design interaction and collaboration that happened in the VE urban design experiment with cross-references to literature reviews and the result of the surveys and protocol analysis. It also discusses how the research contributes to the context of the NSC-BBHTC with evidence of laypeople's meaningful participation in designing New Zealand's future neighbourhood.
Chapter 10 Limitation, Future Research and Conclusion	Reports the limitations of the research in terms of participants, case site, design task, and employed technology. It projects to future research and provides critical reflection on the research. Finally, it concludes with a takeaway paragraph addressing new direction to include stakeholders in the design process where the design instrument empowers non-experts to take part as designers for designing future neighbourhoods.

In the end, the study demonstrates that integrating suitable VR instruments minimises the distance between the laypeople's collective design imagination and its representation during the initial stage of urban design. Through analysis of design conversations and representations, the research has demonstrated that laypeople's collaborative conception, perception, and understanding of spatial volumes within VE contributes to the quality, understanding, and designing of urban spaces and forms. The easy nature of design creation, communication, and collaboration offers an opportunity for experts and non-experts to collaborate in the early stages of urban design. Therefore, it establishes a new direction to include stakeholders in the design process where the intuitive design communication empowers non-experts to participate in a spatial discussion on designing New Zealand's future neighbourhoods.

Chapter 2 Design Representation and Expert's Role

In the last chapter, I laid out the motivation and problem statement of this thesis and described research questions, objectives, significance, and thesis structure.

This chapter articulates the concept of design representation, design agency, and the expert's role in computer-assisted design participation. The practitioners involved in designing a built environment assert their role, knowledge, and design-led thinking in the shaping and humanising of the urban places and spaces (Haarhoff, 2016). Where current advanced technology in design ideation and production already have questioned the role of experts in the design process (Carpo, 2011; Ortega, 2017), which offers new possibilities to make the design production democratic. In those senses, it is essential to understand how experts' roles can be understood to involving non-experts in the VE design process. The first section discusses the role of design representations and using artefacts for design interpretation as an extension of understanding the influential factors of a design agency.

The second section of the chapter discusses the concept of design through action. This section discusses philosophical explanations of how

designers can become critically aware of their agency in the pursuit of empowering publics in design decision-making. The third part discusses the experts' role and digital authorship in architectural practice.

2.1   The Role of Representations in Design

The central issue of representation is the concept of organisations (Akin, 1986). This is based on implicit or explicit organizations found in the realities. Akin describes representations as methods to manipulate symbols that stand for realities, where design is an excellent example of such manipulation. In spatial design practice, designers adapt representation techniques akin to plans, sections, elevations, perspectives, axonometric and isometric drawings, models, and other formats of graphical representations. These tools help the designers to generate alternative solutions and test them before implementing them in real life. The tools of representation also guide the orientation of thoughts, which implies the choice to influence discussion focus (Hanna, 2013). Also, representations minimise the risk of costly errors and facilitating affordance to the designers to test ideas at little cost.

The term 'design' consists of a series of representations to one's mind or the minds of co-workers, clients, and user groups to communicate through external presentations (Akin & Weinel, 1982). In design, designers use suitable means to mentally create design concepts, apply communication channels (media) to express design concepts, and turn the concept into visible artefacts (products) (Chan, 2011). Through this process, the designers and other viewers (or clients) can visualize the design in progress. Designers employ various types of representation media for design communication to facilitate mental operations, procedures, and representations to convert concepts into visual forms. These unique mental operations are parts of design cognition, defined as human intelligence to organize design information and problem structure to create artefacts.

Brown (2003) argues that architectural representation involves first visual cognition for seeing and understanding, second, the organization of primitive information into fundamental forms, and third, the fundamental forms give meaning through association with previous knowledge of the

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world stored in long term memory. As an inevitable part of the design process, designers represent mental outputs internally in their personal mental space and externally on paper or a similar physical medium. During the stage of design, the mental process can be explained as the symbolic processing of information, and it involves the functions of generating design ideas, designing mentally, and visualising mental images. It is clearly a representational activity that involves information processing expressed by a symbolic structure. However, design representation is not the same as a memory representation. The mode of representation in mental space is unique to the propositional graphical mode in which that memory is generally stored and retrieved.

2.1.1 Using Artefacts as the Act of Design Interpretation

Traditional artefacts such as drawings, product samples, models, and now virtual artefacts such as 3D models are used to mediate the journey of a building concept to the actual built form. Most often, these artefacts are produced for different purposes, and obviously for people with different levels of understanding of the design and construction process (Lawson, 2012). The process is known as 'reading' a drawing as a semiotic one, where one person prepares a representation of a building, which is then interpreted by other people. Although drawing is not a language, its codified graphics are used to exchange information between people through translation and interpretation of a sign system (graphic notation, etc.). Even still, drawing representations themselves distort and change the emphasis of our experience more profoundly than we realise. Different kinds of drawings have a different set of 'rules' to interpret, yet these rules remain largely implicit.

Luck (2007) argues that design practice using physical artefacts at the early stages of building design is appropriate for design conversation, as it develops users' understanding of the design. The design conversation builds the user's confidence in the appearance of the design, rather than only through the ability of the artefacts to represent a future reality. The artefacts embody the current knowledge of the design in its present status, but during a conversation, discussion of ideas to modify the design is prompted. Here, the

'act of interpretation' is acting as a part of the design process. Similarly, Bucciarelli (1988) states that design only exists in the collective sense and is realised through conversation and action. Also, Luck and McDonnell (2006) observe that an architect has a range of prompts and conversational repertoires to elicit information from users when discussing a design.

2.2   Design through Action

The representations of design are not the design (Schön, 1983). A design is realized through conversation and action. The activity of design in a socially constructivist sense is developed through the concepts of knowing-in-action and reflection-in-action (Luck, 2007). Design problems are unique in cases where the practitioner put reasons on design decisions and judgements (Schön, 1988). As a social process, design brings different kinds of participants with different roles, interests, backgrounds, points of view, and even different languages to agree on something to be built. Designers express design operations with materials, artefacts made, conditions under which they are made, and especially the manner of making.

Designers make things under uncertainty. They frame a problem of a design situation to solve. They set a designing process to communicate with the users. Designers need a way of explaining the object of designing, which allows them to understand multiple ways of perceiving things and creating commonality. To do that, designers need to inhabit this system, which Schön named "Designers World." Designers build the designers worlds through their thinking. Designers spend time in design worlds to understand the system's constraints and potentials. They develop through the interlocking process of perception, cognition, and notation. The designers world varies with the interest of the designers. Solving the problem of representation depends on a designer's capacity to generate new understanding of a unique design situation. The designers can view accumulated design knowledge in the designers world. Then designers need to employ reasoning about designs. The design reasoning can support why the artefact or decision on design has been made.

Design exists only in a collective sense (Bucciarelli, 1988). In the production of material culture, the activity of design involves many participants. A team of designers with different disciplinary expertise act together to undertake the activity of design; in such cases design can be considered to be a social activity with a minimal discrepancy. Each stakeholder of a design project sees design differently. Moreover, design is also considered a cooperative, inter-subjective activity that participates in the hermeneutic character of all thinking (Coyne & Snodgrass, 1993). Therefore, it is important to allow designers to freely select and negotiate processes and strategies in a collaborative design approach.

Hill (2003) argues that architecture is made by use and design. The practice of an architect can be called design-action. The term 'design-action' describes the critical contribution of users who attempt to establish a relationship between use and design. Design-action offers an inclusive and accessible way of design where designer and user prepare a new aesthetic resulting from their mixed opinions (Petrescu, 2005). The process works with the concrete logic of bricolage rather than with abstract concepts. It offers a presentation rather than a representation. It is an interventionist design and often takes political positions as a catalyst for a social process. Petrescu (2005) refers to Deleuze for stating that such an approach is not a bottom-up approach but stays in the middle. It presents an approach that puts the architects and users in the middle of the creative design process. In such a case, the architect plays the role as per his or her professional obligation, and the users try to operate the process through situational knowledge. Thus, the process stays in the middle between top-down and bottom-up.

2.2.1 Reclaiming Design Agency

The notion of citizen participation has regained momentum over the last decade due to advancements in digital technologies (Friend & Golcher, 2016). This impacts both the realm of national and local politics. Particularly in the domain of art and design, designers are aiming to empower citizens to reclaim agency in the public realm. New theories are being sought, which can mediate various conceptual models of participatory democracy and actual

participatory design practices in a meaningful and rigorous way (Krivý & Kaminer, 2013). Designers who aim to empower citizens in often 'agonistic' spaces need to mediate between the various aspirations of social and political change. Such mediation can take place between different stakeholders, between theory and practice, between ideas and action, between imaginaries and reality, and so on. Designers are now exploring with the aim to "make a difference" (Giddens, 1986) within the established distribution of power. Such exploration in design research examines the "matter of concern" (Latour, 2004) in design practices by analysing material as artefacts and immaterial components as rationality, positionality, etc. These consider the ethical implications of designers' accountability in the service of the public. Therefore, it is essential to explore how designers can become critically aware of their agency in the pursuit of empowering citizens in design decision-making.

2.2.2 Design Thinking

The study of design thinking has been characterised as a method between the hard sciences and the social sciences (Kan & Gero, 2017). In general, the design is considered a highly cognitive process (Dorst, 2011; Lawson, 2006; Schön, 1983). Issues pertaining to design collaboration imbue different approaches that support concept framing, reflecting, critical moving, behaviour, and reasoning among designers in search of a common goal (Idi & Khaidzir, 2018). The early conceptual phases of a design process are often characterized by fuzziness with the highest chances of correcting errors (Craft & Cairns, 2006; Rahimian & Ibrahim, 2011). According to Cross (1999), the design thinking processes hinge around the relationship between internal mental processes and their external expression and representation in sketches. For those, designers have to have a medium that enables initial ideas to be expressed within the design process through reflection, consideration, revision, development, rejection, and returning to the earlier stage of design (Cross, 2001).

Design is a series of decisions that expose the relationships of geometries, materials, and performance (Kan & Gero, 2017). The research

design activities happen as thinking and knowing (Cross, 2001), free-hand sketching and interactions (Lawson, 2006), the social construction of design solutions (Minneman, 1991), and designing by making (John, 1972). Designing as a cognitive activity entails the production of sequential representations of mental and physical artefacts (Goldschmidt, 2004). Tversky (2005) states that when constructing the external or internal representations, designers are engaged in a spatial cognition process in which the representations serve as cognitive supports to memory and information processing. Again, Schön (1992) asserts that with the execution of action and reflection, each level of representation allows designers to interpret their ideas for design solutions. For such a cognitive approach, a design media is something beyond a mere presentation tool, as it stimulates or hampers designers' creativity during design reasoning.

Kazmierczak (2003) says designs as cognitive interfaces enable a process of reconstructing the intended meaning. The approach stresses the semiotic relations between perception and the meaning to explain the perceptual and cultural codes involved in communication. Designers produce designs to communicate with others. The notion of "semiotic" (function or aspect) is defined as a cognitive phenomenon operating symbolically to generate meaning. Such phenomenon initiates a design activity that has the potential to produce creative artefacts (Visser, 2004). Unexpected discoveries during design activities are the stimuli to force design processes to develop and evolve with a solution and eventually spark new ideas about the problem-solving process (Suwa et al., 2000).

2.3   Expert's Role

In this section, I discuss the critical role of architects as facilitators in design participation and their authorship in the current age of information and technology. Information technologies are implanted into design processes, which are now an integral part of design practice. Relying on these technologies in design processes is opening up possibilities to include laypeople as active members in design ideation and generation stages.

2.3.1 Participation in Architecture

Architectural professionals often skip the stages related to participation because of the complex nature of integration into the design process, and the researcher avoids it as it does not fit into their institutional framework (Jones et al., 2013). This is due to the beliefs of the bourgeoisie society who prefer to take care of everything and leave little room for manifestations of independence, and architects generally become part of that group (De Carlo, 2005). As professionals, they become representatives of that class in power. Their professional duties are limited to the study and application of building technology. In all cases, they do not worry about consequences, as long as they do not refer their work to local people. They only focus on the design output. Carlo argues that this is because of the conceptual and operative structure of architecture, which needs to expand. The industrial revolution brought a profound subversion of concept and methods in the design profession along with the reformation of the society. The revival of social reformation raised the issue of participation of locals in the design profession, which later pushed to integrate a participatory design approach.

Luck (2018) argues that current interest in participatory design reflects more progressive forms of architectural practice, where participatory interventions in everyday settings acknowledge and embrace value-pluralism. Architecture practices today engage people in design process as an improvised way which possesses new questions for practice-based design research, as well as the education for architects for twenty-first century practice. He characterises this era with a renewed interest in participatory design. Though earlier Woolley (1985) empirical research on users' satisfaction in participatory architectural design argues the proposition of users' satisfaction of users participation in the design phase. His study investigates two housing project where the users were involved during the design and development phases. Users' satisfaction does not impact much by the design participation but the influence from management and control affects the level of tenant satisfaction.

Petrescu (2005) mentions that a participatory approach challenges the configuration of power relationships within an architecture project. The process should ask who exerts power, and how the power is distributed through the project, aiming to empower both the clients and users to play active roles in the design decision-making process. Petrescu refers to Deleuze (1994) by stating that design desire stands before power, as power is an affectation of desire. In a participatory approach, 'desire' is the precondition of empowering participants through the possibility of expression and design evolution. Participation also can be seen as creating space for discussion through liberating speech. The problem of the conventional consultation process is that it is performed on a certain expected functionality, where the participants have limited room to convey their ideas completely. The way the space of participation is organised has consequences for the results of the discussion. Rigid discussion spaces produce a rigid conclusion whereas liberated speech can produce liberate space.

The challenge of the architectural *design outcome* approach is linked to a way which is inherently a spatial problem-solving discipline. "*In architectural practice, the 'problem' is what gives the profession something to act upon in a specialised manner*" (Jones et al., 2013, p. 26). By not carefully considering people's tacit and latent feelings and values in participatory architectural practice, we unnecessarily limit design's engagement processes to "explicit and observable knowledge about contexts" and negate their ability to explore future alternatives with reference to non-physical attributes of setting (Visser et al., 2005). Frediani (2016) argues that being overly fixated on a *design outcome*, at the cost of participants' tacit and latent feelings and values, can inadvertently "homogenise the needs and aspirations" of participants. In the participatory architectural design literature, there is a tension exists between those participatory processes and tools that seek to facilitate social outcomes and those that seek to implement an architectural design project as the outcome (Armstrong et al., 2014; Frediani, 2016). *Design outcome* focussed participatory processes have generally been well-intentioned but are often criticised as being short-sighted regarding their ability to effectively address issues of power dynamics and social

relationships. They often do not adequately allow for an exploration of conflicting stakeholder perspectives, assumptions and corresponding future visions surrounding architectural and urban issues. Such processes often do not adequately deal with both the complex social structures shaped by various cultural nuances and asymmetries of power, when faced with implementation-driven design projects and short timeframes for project completion (Cooke & Kothari, 2001).

For instance, Broome (2005) reports a mass-produced housing solution in the UK constructed without the views of future residents. Residents were not encouraged to take active roles to decide how the housing would be used and adapted in the future. When that happened, the housing was so inappropriate in design and standard that much of it had to be demolished long before the end of its design life. Broome concludes the article by speculating that effective participation in the construction process can produce a sustainable dwelling for its users. The participation approach can give power to the users and considers people's latent feelings and values beforehand the project completion.

2.3.2 Digital Authorship

Disrupted digital technology is already changing the way architecture is designed and built (Carpo, 2011). On the same note, Ortega (2017) argues that the architecture of industrialisation has been replaced by the architecture of information. These profound changes are largely centred on the foundations on which architectural practices are based, such as representation, information management, and virtuality. Carpo's arguments highlight the participatory and communal ethos of the Gothic age and Modern period with the current era of design and fabrication software. The arguments are that the new mechanical and industrial means of reproduction demand a more integrated way of combining thought and know-how. Both the Renaissance and Modernist modes of reproduction imagined a universe of forms determined by exact repetition via visual imprints, which are now replaced by digital reproduction where such creation happens via the exact transmission of the invisible algorithm. The shift from the physical to the

informational enables and encourages new opportunities to make an infinite variety of an initial condition of the form. Carpo (2011) and Ortega (2017) recount how the first generation of digital design in the 1990s focused on producing variation but still relied on proprietary techniques and authorial decisions. In contrast, the more interactive open source-based software has a greater potential to redistribute intellectual and physical labour. The ease and speed of Computer-Aided Architectural Design (CAAD) software can accommodate and even analyse new inputs. Even the nature of the interfaces enables anybody to become involved in the design process to directly affect a project's shapes, spaces, or surfaces (Salomon, 2011). It is possible due to the current increase in computational capacity and the ability to directly translate information of things to a digitally controlled design process. As an example of fabrication, slight differences in design can produce a customised version of a building with no extra cost. Variation is built into the system. In such a case, the design representation has become dynamic. So, authorship may not be dead, but creates the interface with the algorithm, which creates the generic forms or parameters that can subsequently be manipulated and adjusted by others. However, according to Salmon (2011), Carpo's book fails to provide enough evidence to make it historically rigorous proof. Reminiscent of Alberti's notion on tools and way of working that can never be aesthetically or politically neutral, Carpo's work also ends without a solution for the problem with his own interpretation, but raises a keen awareness of the dilemma and the conceptual and disciplinary implication of it.

In a similar note, Fok and Picon (2017) claim that digital technologies are disrupting the conventional way of doing things. This raises the topic of design ownership; in other words, the legal status of the various forms of involvement in the design process. The architectural legal framework for plans and drawings is today showing limitation because of the extraordinary diversification of architects' interventions, services, and products, and above all, because of their complex modes of interaction and layering in a practice that has been completely transformed by digital technologies. According to Picon (2016), a new economy of the architectural field is emerging in which

information circulates in a manner that evokes blood flow. Ideas have become as mobile as the lines of computational code that convey them. Such intricate trajectories have made possible various types of ownership. With code and computers, a number of traditional oppositions appear no longer relevant. Notions of abstract and concrete have, for instance, become seamlessly linked to one another. Uniqueness and variation can now be reconciled. Due to the pervasive nature of the code, the design world has become more connected and fluid.

2.4   Summary

Design is realized through conversation and action (Luck, 2007; Schön, 1983, 1988). It is a social process, as all design problems are unique and include different kinds of participants with different roles, interests, backgrounds, points of view, and even different languages to come to a consensus on building something. Designers think in relationship with internal mental processes, external expression and representation in medium (Cross, 2001). Design thinking is considered as a highly cognitive process (Dorst, 2011; Lawson, 2006) and has been characterised by mental and physical artefacts (Goldschmidt, 2004). Designers need a way to explain the artefacts to be designed through creating multiple avenues of perceiving the design, as well as commonality. To get that perceptual understanding of the design artefacts, the designers have to create a conceptual world to interpret the design actions. The conceptual world of the designers can be transmitted to others through the right type of representation techniques, which allows communication with the proposed design concept. In an architectural design process, the representation involves visual cognition for seeing and understanding, information of forms and the meaning of forms in association with previous knowledge of the world stored in long term memory (Brown, 2003). And, the representation tools guide the orientation of thoughts, which provides the choice of discussion in the design process (Hanna, 2013).

Designers use a wide range of medium to communicate and represent their design ideas (Chan, 2011). The traditional design artefacts are now coupled with computerised representation modes as virtual 3D artefacts.

Physical artefacts in building design initiate conversation between users and designers in the early stage of the design development, and such communication builds the user's confidence in the appearance of the new design. It prompts a discussion of ideas to modify the design. In such a case the 'act of interpretation' is becoming a part of the design process, as design only exists in the collective sense (Bucciarelli, 1988). Considering that, the thesis speculates that virtual 3D artefacts can interpret and represent urban forms with the capability of initiating a conversation between users and designers towards meaningful design outcomes.

The revival of social reformation encourages the inclusion of participatory design approach in the architectural design process (De Carlo, 2005; Jones et al., 2013; Petrescu, 2005). To continue a design process without creating repetition, and to avoid homogeneity and recurrence of the same, one needs to reinvent the design continuity through the spontaneous participation of people. It means design iteration can be spontaneous if people are engaged in the design process. The recent advancement in computing power of digital technology supports the continuity of design iteration which possesses representation techniques for non-experts to involve in the design process. Such technology-driven design representation and iteration tools allow non-experts to take part actively in design ideation and generation stages. Which reduces the power gap between non-experts and experts, and changes the role of experts from designers to facilitators.

Chapter 3 Communication and Participation in Urban Design

In the last chapter, I laid out the arguments for leveraging laypeople in 3D artefact representation and interpretation by using computational technology.

In this chapter, I discuss the disciplinary ambiguities of the urban design processes, because it is necessary to understand the scope of urban design compared to architecture and urban planning. It also includes sections on the need for mediation between conventional and participatory urban design processes, the medium of those design processes, the role of visualisation in design communication, and New Zealand's urban design toolkit.

3.1   Urban Design Participation

This section discusses the disciplinary ambiguities of urban design, the concept of participatory design process and design, and the need for mediation in the participatory design process.

3.1.1 Disciplinary Ambiguities

Urban design process deals with the complex phenomenon of neighbourhoods, cities, and regions. It is always difficult to foresee the future of this diverse problem. Urban designers and planners examine existing conditions and propose future speculation by incorporating a wide diversity of information in their analysis and solution (Madanipour, 1997). The design processes also have to deal with the ambiguities of the role of professionals and the association with different sectors of the political economy. This includes the participation of local people in the design process. Methods of design communication support urban professionals to convey as well as receive the end-users' perspectives on their urban settings. Facilitating a conversation with end-users in the design process not only informs them about the future design but also allows the end-users to be an active part of the design process. The concept of involving end-users in the design process and the conventional approach of designers being involved in the design process along with other ranges of activities have raised the question of disciplinary ambiguities of the urban design process.

The definition of urban design process is still in a state of ambiguity due to its converging nature with a wide range of activities (Madanipour, 1996). The urban design process can be seen on a broad spectrum from producing visual qualities of urban places to the transformation of abstract urban spaces. In general, urban designers are interested in this process and its products. Urban design can be seen as a multidisciplinary activity of shaping and managing urban environments, interested in both the process of shaping and the spaces it shapes. The process can be understood in three different angles: technical, social, and creative. It represents a technical process that equates with big architecture and engineering, which as a social interaction seeks new institutional arrangements and allows the designer to produce spaces by interacting with the subjects in a creative process of aesthetic understanding. The process gives structure and reality to 2D master plans and planning briefs before architectural or engineering design can take place. Others also see urban design as a design of the built-up area at the local scale, including the grouping of buildings for different uses, the movement systems,

and the services associated with them. For New Zealand, researchers like Gunder (2011) argue on the side of considering urban design as a subfield of urban planning, which deals mainly with urban form, liveability, and aesthetics. Allen (2018) argues in the research of NSC-BBHTC that the theory of neighbourhood within urban planning is connected to socio-spatial understandings, where there is a connection made between the physical spaces and built form of an environment and the emotional and physical well-being of residents and the resultant quality of urban life they experience. In the attempt to define urban design, some are looking at its involvement with the physical fabric, while others are focusing on its scale, congruence with planning and architecture, political and management aspects, or place in the planning process. However, despite such deferential controversy, the most commonly accepted definition allows for dealing with urban forms as three-dimensional places for people and perceptual understanding of surrounding buildings. In small-scale intervention, urban design deals with issues close to the aesthetic and spatial concerns of art and architecture.

3.1.2 Concept of Participatory Design

"*Participatory design*" is a collection of design approaches, methods, tools and techniques that are shared between many disciplines. Over the past decades, a shift has taken place towards "participatory" design approach where residents are increasingly involved in the decision-making process (Van Dijk et al., 2014). Participatory architectural design and stakeholder participation in community design can increase the chance of successful project implementation improvements, as stakeholders are more likely to support plans that can reduce risk and timeframes for project completion (Majale, 2005). Carefully orchestrated participatory processes generally also result in projects that are well-suited to community needs. They can be transformative through building the capacity of those who are traditionally omitted from city building procedures to engage with development processes (Angel, 1983). In this context, participatory urban design can involve people who have generally marginalised to express opinions and ideas and provides opportunities for them to be included in the decision making that will impact their lives, livelihoods, and wellbeing (Frediani et al., 2011). Majale (2008)

argues that a participatory approach enables residents to provide meaningful input into the project, can lead to the empowerment of the residents. Macpherson and Antonacopoulou (2013) explain that participation allows people to expand their capabilities, and in turn, their freedom. Through an exploration of social complexities involved in participatory design processes, participants can be stimulated to "*share diverse opinions, and aspirations [and] thus deepen their understanding of the self, others, norms and institutions*" (Frediani & Boano, 2012, p. 216). DiSalvo et al. (2010) argue that participatory design processes can become processes that are guided by normative principles of being open to contestation and reconfiguration. They can function as a catalyst for the transformation of physical urban environments and socio-cultural contexts. This mode of participatory architectural design is in direct opposition to dominant modes of pseudo-participation, where the design facilitators cultivate an impression of openness but are careful to retain decision-making in their own hands (Arnstein, 1969; Cooke & Kothari, 2001; Frediani & Boano, 2012).

While the terms "participatory design" and "co-design" are often used interchangeably in the literature, co-design is actually a particular type of participatory design whereby expert designers and people not trained in design work together in collective creative ways throughout the whole design process (Sanders & Stappers, 2008). Participatory design is much broader and encompasses actions at different stages of the design process, as well as being applicable to the design process holistically. *Participatory design tools,* which include digital and physical games, mapping instruments, and visualisation systems among others*,* are used in participatory design activities to engage stakeholders in design thinking (Sanders et al., 2010). They support collaborative design enquiry and bring together a network of actors with different backgrounds, competencies and experiences (Brandt et al., 2012).

According to Armstrong et al. (2014), *social design* participatory processes are less focussed on the production of design outcomes, and instead focus primarily on building mutual understanding, networks and relationships between participants—or *social capital*. These are often motivated by challenging the drivers of socio-political issues and improving the conditions

for a disadvantaged and often confined community. Social design processes can struggle to interface with design processes that meet the diverse needs of communities. Armstrong et al. define *social design* as participatory approaches to researching, generating and realising new ways to make change happen towards collective and social ends, rather than predominantly commercial objectives (Armstrong et al., 2014).

3.1.2.1 As a Social Process

Henri Lefebvre defines a concept of two worlds in terms of social and spatial design understanding for experts and people (Lefebvre, 2003). In his definition, the experts' world is for abstract space and the people's world is for concrete space. Experts such as planners, architects, and designers create the physical environment in the concrete space through the tools of abstraction and representation. This is why people in concrete space need to conceive design through abstract space. Since modernism, these two worlds were separated, where professionalism always stood apart, and people were treated as the subject of reactive information. A new form of in-between space can be formed when these two worlds re-join (Lee, 2007; Lee, 2008), where the realm of design collaboration comes in.

Lee (2008) points that there is difference between Participatory Design (PD) and Design Participation (DP). PD is one of the rules to control the design game and DP is a new attitude towards playing the game that try to change the nature of the game. Understanding the field of DP can help designers to design with people's interest as methods to apply collaborative design thinking in different everyday situations. Lee develops a diagram to show the three modes of participation (Figure 3). He mentions that DP for collaboration happens in between these two realms, which aims to encourage the design process (Lee, 2006). According to him designers should work as design agents to adapt different roles as design generators with professionals, design facilitators designing with people and design developers working with design community. Design developers work with design community to transform design processes for participation. Design facilitators design with people to transfer design knowledge to emancipate people to improve their lives. Design generators collaborate with professionals to explore design

thinking to different implications. However, Lee's concept contradicts with the concept of Lyotard (1984), that DP practitioners work on the system of performativity. They are mission-oriented, and the knowledge is reduced to its instrumental value. It is obvious that to make the designer-user game more interesting, it is better to have no fixed rules. This procedure of involving people is called "The Alternative Culture" according to Banham (1972), where he defines design participation as 'do-it-yourself' in which people invent their own rules. The drawback of this concept is that it completely ignores the role of the designer.
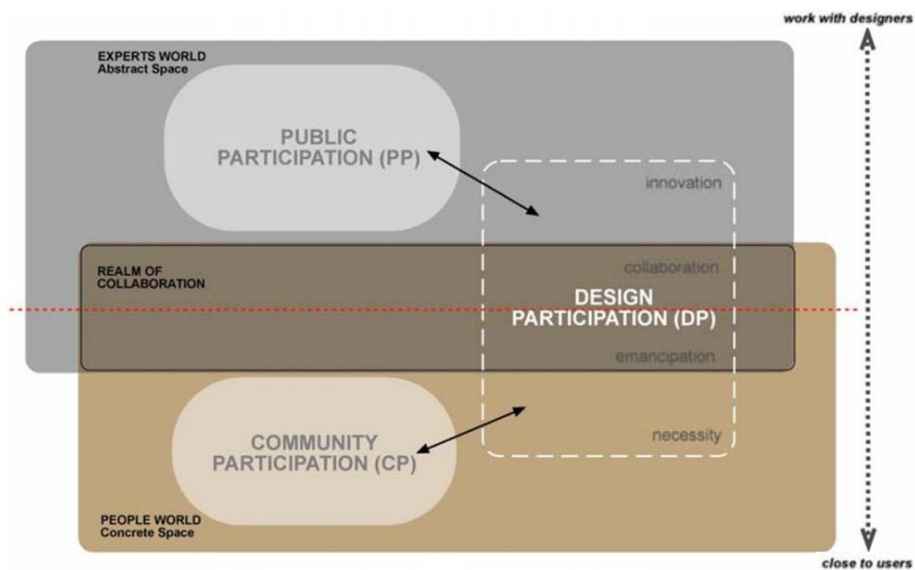
Figure 3 Design, Public, and Community Participation in the abstract and concrete space (Lee, 2006).

Participatory design approaches are considered to reflect design as a social process, which extends the sphere of design activities beyond the designer (Luck, 2003). Users take part in the social process of design and play an active part in problem raising, discussion, and decision-making processes, which are part of the early design stage of the project. Also, in the early stage of design, the participatory process concerns issues related to representation. It is the stage when users' needs and expectations are being expressed. As the users become the active part of the design process, the boundary between 'designer' and 'user' becomes blurred. Including users' preferences in space will change the properties of that space, making their own alteration through the act of occupation to alter that space. The user designs the space by occupying the space.

In a general sense, the purpose of citizen participation is to inform the people, get their reactions on proposed actions, and engage in a problem-solving situation to come up with an accepted solution for everyone (Creighton, 1996; Sanoff, 2008). The legitimacy of this decision results in the process of deciding through fair, open, and democratic methods. In another sense, civic participation supports the dialogue between citizen and public official regarding resources to meet their needs (Sanoff, 2000). This dialogue may take the form of visioning a design proposition. In the design process, the objectives of participation are clearly to involve a diverse group of people in the decision-making process (Wulz, 1986). Participation is effective when the task of design participation is thought to involve community people. Planning is required for a designer to come up with a participation method that can meet the expectations of the community people. Most often in such a case, the professional's role is to facilitate the participant's ability to reach decisions about the aspects of their environment through an easily understood process. Such facilitation allows us to design a method or tool that can engage people who are not professionally trained to organise themselves to create a change in the design environment.

3.1.2.2   *Participatory Goals, Objectives and Experiences*

In the participatory process, it is necessary to identify goals and objectives in planning for participation (Sanoff, 1988). It is also necessary to analyse the techniques that are available with the resources they require. Techniques such as surveys, review boards, neighbourhood meetings, conferences, task forces, workshops and interviews, represent a few of the multiple options of participatory planning. Techniques get purpose with the goals and objectives. The goals and objectives of participation allow the participants to perceive the type of the participation. Obviously, it also depends upon the types of issue and people involved in the process. The people who are involved in participation, they need the feeling of control in their decision-making process which add new capacity to their conventional approach. In that regards, design participation is the only way that their needs and values can be taken into consideration.

Effective citizen participation requires the provision of effective communication media in order to provide suitable grounds for design participation (Sanoff, 1988). User participation in the design shows that the main source of user satisfaction is not so much the degree to which his or her needs have been met, but the feeling of having influence the decision. That can be achieved by providing the feeling of control in their decision-making process with clearly perceived goals and objectives of type of participation.

Participation can be categorised in four different categories, awareness, perception, decision-making and implementation (Sanoff, 1988). Awareness involves discovering and rediscovering the realities of a given environment or situation so that everyone in the "Take part" process is talking the same language based on their experiences in the field where change is proposed. In that case, the participatory tool designers need to ensure the possible involved awareness during the process. Perceptions entail going from awareness of the situation to understanding it, and its physical, social, cultural and economic ramifications. It means sharing with each other so that the understanding, objectives and expectations of all participants become resources for designing. Decision-making phase concentrates on working from awareness and perception to a program for the situation under consideration. In it, participants make actual physical designs based on their priorities. The achieved quality of awareness and perception lead the participants to involve in the decision-making process. Implementation process mostly does not come in community-based planning after awareness, perception and decision-making stages, because it includes people's responsibilities to see the final results of their decisions. The process also becomes complex as it requires the real implementation of the decided ideas.

3.1.2.3   *Concept of Tools and Techniques*

Participatory design approach comes with a varied set of toolboxes (Brandt et al., 2012; Sanoff, 2000). The selection of tools and techniques brings ownership of the participants on the results. Participatory designers pioneered new approaches to designing with users, such as prototyping, future workshops and design games that have become widely accepted and used

within the design community at large. In the early year, tools and techniques of participation were seen as an essential means to remedy the professional process of systems design. Today the tools and techniques are brought forward the practices of design participation as integral parts of the activities of involved people. However, the design approach gets criticism on mainstream design and technological integration for not accommodating the multiple voices of users.

The concepts of tools and techniques were still defined along the conventional lines of system design (Brandt et al., 2012). The idea of the technique is here defined as 'a specific direction for performing a certain activity. It may involve activities for data gathering, processing and presentation, or project management. In participatory design, it refers to a coherent set of organising principles and general guidelines for how to carry out a design process from start to finish (Bratteteig et al., 2012). The guideline must be carefully selected, adapted and appropriated to the specific project and situation at hand. Techniques may be used independently of how the design project is planned' (Bødker et al., 2009). In this sense, prototyping may be the technique which Sanders and Stappers (2008) suggested as 'maketools' with participatory mindset. According to Brandt et al. this way of conceiving of tools and techniques is slightly deceptive as they can be applied irrespectively of the purpose and values of a specific project. What is essential is that tools and techniques are appropriated in a design practice while concerning with the problem at hand. This means that the concern for choosing tools and adopting participatory mindsets is less one of doing things right and more a question of being aware of what can be accomplished by those particular tools and techniques as parts of the design process.

3.1.2.4 *Computational Systems and Design Participation*

The concept of participatory design has changed significantly with the inclusion of the computerised system in the workplace (Ehn, 2017). The earlier form of the participatory design approach can be traced back to citizen participation in decision-making since the period of Plato's Republic (Sanoff, 2008). Plato's concepts of freedom of speech, voting, assembly, and equal

rights support the notion of modern-day people's interests in taking part in decisions that affect their lives. Due to the difficulty of including all people in decision-making processes, people started to create institutions and organizations as representatives of their interests. In the 1960s, the rejection of conventional design practice and including people in the design process took a new turn with the inclusion of the computer system in the workplace. Around the 1970s in Europe a new form of participatory design grew when labour union leaders sought to enable workers to have more influence in the workplace with the inclusion of the computer system. Several projects set out in the Scandinavian region to find the most effective ways to include computer-systems in organizations to promote a high quality working life. The underlying concept of developing computer-based tools was to extend the traditional practical understanding of tools and materials used for a particular profession. Since then, the effort towards designing a computer system started to consider the specific labour process to make the tools useful. In that context, Cross (1972) proposed that computer-aided design and human-computer interaction could be potentially combined to create a computational design system for design participation. The fundamental concepts of early participatory design have shifted towards empowering individuals, due to the technology that has facilitated the emergence of increasingly autonomous systems through the act and makes decisions based on computational feedback (Bannon et al., 2018).

Participatory design engages users in the design of new information technology (Bratteteig et al., 2012). Methods are 'recipe' for participatory design. Methods are prescriptions of how participatory design projects can be set up so that users are enabled to take an active part in the activities and decisions by designing and building new information technology. Participatory design not only includes tools and techniques but also the organising techniques and general guidelines for the process. Traditionally the design methods concerned with information technology as 'system development' (Andersen et al., 1990). Information technology is a complex technical artefact whose functionality depends on a computer program. It is extremely malleable but at the same time provides challenges as the program

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does not resemble the final product that the user will experience. The computational program has to be developed for the user to experience its interaction and its behaviour. Therefore, the challenge is how to develop a highly complex piece of technology and at the same time be flexible for learning processes resulting in changes to both the interface and the functionality of the technology throughout the design process.

3.1.3 Need for Mediation in Participatory Urban Design Process

The conventional urban design process includes institutionalised techniques and knowledge of trained professionals who utilise empirical knowledge in dealing and designing an urban situation, which only can be understood by the fraternity of those institutions. Conventional urban design techniques cannot offer flexibility to cater to a wide range of social issues in the design process (Kiddle, 2011). Methods like design charrettes and planning workshops already have accepted in such democratic engagement in design processes (Batchelor & Lewis, 1985; Knevitt & Wates, 1987; Steinø et al., 2013). However, in spite of such established methods, there are still differences that exist in thinking and communicating language between experts and laypeople (Forester, 1988; Friedman, 1973). The lack of engaging ways eventually pushes researchers to rethink a new form of design-decision making platforms where non-experts can fully understand the spatial implications of planning and design decisions. Previous collaboration methods to develop concepts in the early design phase cannot involve end-users in the discussion by inhabiting the environment.

Bottom-up design approaches involve local players either through design consultation or by collaboration. In the 1990s, communicative approaches equated planning theory to political theory (Pissourios, 2014). Healey (1997) indicates the demands of public participation in decision-making for more accountability on the part of a local politician, officials, and the increasing role and power of technical experts. This brings the shift from a top-down to a bottom-up approach in urban planning practices (Murray et al., 2009). The bottom-up approach corresponds to the existence of a community that has specific needs, problems, and expectations that are

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different from those of other communities (Pissourios, 2014). The participatory bottom-up process loses its efficiency when the population size increases, which slows down the process of urban intervention and consumes more time in the process. In particular, the arrangement of gathering various stakeholders of the community in an open-ended discussion requires more time to reach an agreement. Thus, in large communities, the participatory bottom-up approaches are inefficient. Naess (2001) also argues that bottom-up approaches are unable to deal with super local facilities, and their implementation becomes cumbersome. Thus, the top-down approach is inevitably the only available choice for regional and spatial planning practices, and bottom-up approaches are limited to the local planning of small settlements (Pissourios, 2014), which indicates the intervention in the urban design process.

3.2   Communication in Urban Design Processes

Participatory urban design approach encourages direct communication in urban design. The demands of public participation as a bottom-up approach in decision-making gained accountability on the parts of stakeholders (Healey, 1997). Participation concerning design processes can be defined as information exchange (Sanoff, 2000). In that sense, visualizing 3D information helps ordinary people to see what their ideas look like during the design process (Walters, 2007). The conventional participatory urban design process is based on pen and pencil, paper maps, photographs, and physical models (Al-Kodmany, 2001). Such visualisation techniques still provide specific visual consequences governing the design of data representation (Tufte & Robins, 1997).

Generally, the term "communication" means a sense-making process between virtual and actual (Deleuze, 1990). Sense follows the logic of virtual events, as it comes into existence through expressions. The sense is purely virtual, which constantly actualizes through communication (Luhmann, 2004). Around the 1970s, there was a scholarly debate on the question of how a process of systematisation in a design methodology could be made accessible to laypeople. Till (2005) criticises that the fundamental

contradiction of this design approach is between seemingly authoritarian aesthetics and high economical and technical expense on the one hand, and the social reality on the other. Likewise, Hofmann (2014) argues that the transparent design process alone is not enough to enable non-expert users to participate, since the drawings and technical information are only comprehensible to the experts. Again, regarding communication in the urban design process, Steinø and Veirum (2005) have pointed out that the process is time and resource consuming. It also faces the barrier of differences in thinking and language between professionals and laypeople. Moreover, lack of detailing in the early design phase does not allow laypeople to understand the design, while ironically, as the level of detailing increases and makes it easier to understand, it can no longer be changed without considerable expenses in terms of time and resources (Steinø et al., 2013; Steinø & Veirum, 2005).

The need for better representations of urban form encouraged professionals to adapt techniques from other disciplines such as media technology (Bosselmann, 1998). It is accepted that good professional representations open up the process of design evaluation and improve the credibility of design professionals. Earlier researchers who were interested in improving visual communication in city design wanted to make others aware of good urban form, but they were dissatisfied with conventional media because they could not convey the experience of the proposed urban form. They felt that a professional operating in a pluralistic society could not afford its idiosyncratic graphic language, which was based on conventional drawing methods like plans as maps, sections, elevations, and perspectives. An effective visualisation is needed in communicating ideas with others (Langendorf, 1992). Professional designers and planners generally know the limitations of representation, but they take for granted how representation influences design thinking. They acquire the necessary skills to represent what exists and what might be transformed into reality. It is accepted that the richness and complexity of the real world cannot be completely represented; that is why they select necessary parts of reality to represent an abstract form of actual conditions. The inclusion of computerised production of images has

changed the way they do their work and improves their thinking about design, offering a new understanding of urban spaces.

3.3 Urban Design Tools in New Zealand

I mentioned in Chapter 1.1 as research motivation that the NSC-BBHTC challenge (NSC, 2017) is looking for an innovative co-creative urban design process. The challenge aims to develop an innovative method to investigate urban design collaboration. It also questions whether digital media can be implemented as a 'driver of change' for neighbourhood design. The challenge has developed a base on New Zealand's government action policy and principles for urban designers to achieve healthy, safe, and attractive places for flourishing business, social, and cultural life (Gunder, 2011; Higgins, 2010). In the same context, Haarhoff (2016) argues that an urban design practitioner should assert their role, knowledge, and design-led thinking in the shaping and humanising of the urban places and spaces. Under the umbrella of the Sustainable Development Programme of Action, the Ministry of the Environment has published several key components for this national initiatives (Mfe.govt.nz, 2019a). One of the action documents presents the value of urban design through economic, environmental, and social benefits, named as *New Zealand Urban Design Protocol*. In particular, it suggests the need for user participation in the design decision-making process and prescribes several design toolkits. The published document for urban design is named "Urban Design Toolkit," and is a living, web-based resource (Mfe.govt.nz, 2009). It is a collaborative effort and includes participation of a large number of professional people in different workshops. The toolkit has been designed to help urban designers to work together more effectively with a wide variety of tools and provides a common vocabulary for urban design issues. It provides appropriate tools and techniques to achieve high-quality urban design solutions for New Zealand's towns and cities.

In the tool kit, section two informs several community participation tools. The suggestive tools are for encouraging community involvement and informing initiatives to them. In the report, community participation tools are described as fundamental tools for developing appropriate and effective urban

design solutions through the engagement of the community and users as an influential part of the urban design decision-making processes. These tools are used to identify the community's concerns and issues, informing necessary needs, values, and expectation for users, and creating opportunities for community involvement in the design decision-making process. The tools range from a community meeting, workshop, and focus group discussion to an interactive display, interactive model, participatory appraisal (a mixed-method), and urban design games.

Participatory appraisal technique suggests an approach to gain a rapid, in-depth understanding of a community or certain aspects of a community through using visual techniques like models, ranking, discussions, mapping, or community inventory (Mfe.govt.nz, 2009). It encourages qualified facilitators to help to select the right mix of creative and targeted techniques. Interactive visual displays can be used to encourage wide participation through interaction between participants as they can respond to other participant's decision and also add their view on the display. Similarly, the interactive model technique suggests using simple blocks of various sizes and shapes representing urban building elements. The blocks are used to construct configurations of built urban form to scale as a way of exploring alternative three-dimensional design options for a site. The technique has been encouraged to visualise the widest variety of configurations to new scenarios. The idea is to promote participation and enable members of the community and other non-designers to get involved in the design process and to understand the implications of decisions on three-dimensional form and space. This interactive modelling technique has been suggested to employ a computer simulation technique as a means of developing ideas and systematically exploring design, growth, or planning options for a town or city under a range of potential economic, social, and development scenarios. The toolkit suggests that scenarios may relate to any combinations of variables; for example, building heights, the intensity of development, town boundary conditions, or regional population growth. Such a scenario building also informs debate and decision-making in participatory land-use mapping.

3.4 Summary

In traditional urban design process, the citizen cannot fully engage in the professional's design process. Professionals are trained to solve problems based on their interpretation of others' perceived needs. In contrary, participatory design process allows collective discussion, which brings citizen's accountability in the decision-making process. Participatory process in community design increases the chance of successful project implementation. Carefully orchestrated participatory processes bring results that are well-suited to the community needs. They build the capacity for those who are traditionally omitted from city building procedures. Their decision-making through the process impact their lives, livelihoods, and wellbeing. The approach also enables the citizen to provide meaningful input into the decision-making process, which leads to the empowerment of the citizen. The participatory process can act as a catalyst to transform physical urban environments and socio-cultural contexts. However, the process gets criticism due to taking considerable time, cost and most often ends without any agreement. The quality of design participation depends on the type of communication tools which leverage citizen to participate in authentic manners.

In participatory process, designers use varied tools and techniques to communicate with the citizen. Planning is required for a designer to come up with a participation method along with the tool that can meet the expectations of the community people. To do that, sometimes, the designer develops the tool. The main challenge to developing a tool is to make sure the capability of sharing a common understanding of the design problem. The process should have clear goals and objectives so that the people can get the feeling of control of their decision. Also, awareness of each other activities via the same language communication brings the state of perception during the process. Design task as a part of the technique orients the participants in the process. Designers keep in mind that people are not professionally trained to make a change in the design environment. So, the artefacts of the design tools should have the capability to represent people imagination communicatively so that other co-designers could perceive the generated ideas at the same time.

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This shared understanding of perceived imagination leads the discussion towards a meaningful outcome. Besides, good representation of the used artefacts in the process can open the scope of design evaluation and improves the credibility of the designers as it influences design thinking by offering a new understanding of the environment. In such a case, technological tools enhance that participatory process more effectively, as they provide a better representation of design artefacts.

A computer simulation tool with the capability of interaction can enhance public participation as a part of participatory approach, which is suggested by New Zealand's urban design toolkit (Mfe.govt.nz, 2009). Primarily, the toolkit highlights the importance of using design consultation techniques, which limits the integration of end-users to act as designers. They also encourage the use of simple block-based interactive visualisation tools to engage people. The technique has been encouraged to visualise the widest variety of configurations to new scenarios with a three-dimensional understanding of form and spaces. As an extension, the toolkit suggests for computer simulation technique for interactive participation. In this regard, the study speculates that a sophisticated computer-based tool with the capability of producing communicative design representation in the participation process can leverage New Zealand's citizen to be an active part in the urban design process. They can design together as a team and interpret design ideas collectively. Through the process, they build capacity among them by having the feeling of control on their decisions.

Chapter 4 Communication and Visualisation in Virtual Environment

In the last chapter, I laid out arguments on the concept of participatory urban design and the concept of design communication with a participatory design approach. I also mentioned the type of urban design toolkits practised in New Zealand where there is an opportunity to integrate virtual representation of 3D artefacts. An extension of that, this chapter gives an overview of the concept of communication and visualisation in VEs. It also gives a brief explanation of the concept of VR, perceptual understanding in IVE, the nascent of virtual three-dimensionality, the concept of collaborative design in VE, and the concept of simulation in urban design. This chapter also provides a brief overview of design decision-making in VE.

Communication and visualisation is the heart of any urban design system. Like norms, it used to be done in 2D forms such as plans, maps, and perspective drawings (Smith et al., 1998). Through time, the easy availability of affordable equipment and software for VE has transformed those norms of

communication and visualisation in architecture and urban design practices (Schnabel & Kvan, 2002, 2003). VE facilitates perceptual design understandings between designers and clients. With the help of VE, the designers have a greater potentiality to perceive 3D understanding of space and volumes. Extension of VE to Immersive-VE (IVE) offers the user an active and real-time interaction with the design and therefore, to some extent, ensures a real sense of presence.

Besides, the representation of 3D artefacts in a VE and its conceptual interpretation during design stages facilitates designers to initiate new design ideas. There is an underlying concept behind such cognitive initiation and interpretation of designers. Moreover, recent evolution in computational tools facilitates more opportunity for designers to create their own suitable design communication tools, which also can be seen through the development of an interface for design interpretations.

4.1   Communication in Virtual Environments

This section discusses how architectural and urban design presentation techniques have been influenced by the intrusion of computer simulation techniques and how we conceive the idea of VR and beyond towards perceptual understanding in VE.

After the 1970s, the history of visualisation and communication turned to assert the importance of presenting architecture as a place to perceive the relationship of physical settings (Moloney, 2009). The architectural theoreticians of that period asserted the importance of stimulated and informed visualisation techniques like photographic collage, the re-emergence of perspective drawing, sequential sketch techniques, the use of urban figure-ground analysis, and the use of physical site models. In a later period, such temporal technique of narration and visualisation were overshadowed by the widespread uptake of computer-aided architectural design (CAAD). Now, the process of generating a digital representation involves the application of automatic visualization software, which has affordance and immediacy to move from the direct generation of design representation using pencil and paper to the digitally generated equivalent

(Brown, 2003). Eventually, the increase of computer graphics power leveraged design professionals to get into more sophisticated and intuitive design interventions (Moloney, 2009). In recent days, the VR technologies have become more sophisticated and efficient, so that professionals can present their design ideas in the sense of real environment, and can integrate laypeople's active participation within the design process.

4.1.1 Concept of Virtual Reality

Virtual Reality (VR) breaks out of the bounds of reality and accomplishes things that cannot be done in physical reality (Slater & Sanchez-Vives, 2016). In general terms, VR represents a computer-generated world involving human senses and produced in real-time by the participant's actions (Bertol & Foell, 1997). The real-time responsiveness of the computer by the participant's action separates VR from other computer implications. The other essential factor in VR is its quality of immersion surrounding by a 3D environment. Basically, VR presents stimuli in three dimensions (Wilson & Soranzo, 2015). In short, VR acts as a medium of human communication through the means of sharing information and experiences among people (Sherman & Craig, 2003). It represents technology to imitate certain aspects of reality.

In a more profound sense, VR coincides with Jean Baudrillard's (1981) 'hyperreality' as an operational condition of a thing or idea that is defined by what it does rather than what it represents. He used the word 'simulation' to describe the working concept of hyperreality. The word 'simulation' denotes an experience that 'feels real' produced by artificial means, usually (but not necessarily) digital. In the process of simulation, the user implicitly agrees to overlook the obvious fact that it is produced by radically different means of experience than that which it evokes (Scheer, 2016). At the end of the process, only the experience matters, not the way it is produced. According to Scheer (2016), the main characteristic of hyperreal visibility is the pervasive elimination of the differences between image and reality. It is a deterministic approach not to experience images as realistic. Such fidelity to the pervasive nature puts a value on the attributes of visual representation. The differences between reality and digitally produced images

do not pass unnoticed, rather the pervasive nature of fidelity convinces the user to accept the experience. It explains how hyperreality manifests the aspects of vision. Vision is accepted as the primary sense through which people receive information about their world. The phenomenon of vision in the simulated virtual world provides more informative visual information to the users. Computation tools can facilitate simulation. Here, the research employs a VR instrument to produce a hyperreal vision of urban scenarios for laypeople. The instrument affords the perception of 3D artefacts as a real representation of urban form.

In a VE, one complication that arises in the perception of space (Wilson & Soranzo, 2015). Many studies have reported the disparity between judgements of distance and perceptual actions such as moving in the VE. It has been observed that users consistently underestimate the size of the environment and the size of the objects. This is due to the varying fields of view in the environment. Usually what we see in the VR environment as an object is a series of images mediated by a display. While a user's vision is focused on the series of the image that builds the virtual object, the object appears in a different location. This happens because the user's eyes are continuously converging on the virtual object. This effect helps the users to get continuous visual feedback while walking through the VE.

In their first chapter, Fuchs et al. (2011) propose a taxonomy-based theoretical functions regarding the individual's perception of reality, which has been conceptualised through the notions of time and space. The interaction happens as per the immutable physical laws. In their words:

> *Virtual reality will help him to come out the physical reality to virtually change time, place and (or) the type of interaction: interaction with an environment simulating the reality or interaction with an imaginary and symbolic world.* (Fuchs et al., 2011, p. 7)

The technical definition of VR follows:

> *Virtual reality is a scientific and technical domain that uses computer science (1) and behavioural interfaces (IAP2) to simulate in a virtual world (3) the behaviour of 3D entities, which interact in real-time (4)*

with each other and with one or more users in pseudo-natural immersion (5) via sensorimotor channels. (Fuchs et al., 2011, p. 8)

The fundamental principle of VR can be shown in a loop figure (Figure 4). The user acts in the VE(s) by user motor interfaces, which capture their actions (gestures, movements, voice, etc.) (Fuchs et al., 2011). In the Virtual World (VW) these activities are transferred to the computer as a calculator, which interprets them as a request to modify the environment. In agreement with the request of modification, the computer makes the changes in the VE and reacts with sensorial stimulus like images, sounds, effects, etc., to be delivered to sensorial interfaces. The loop presents an interactive VE of behavioural transposition between perception, cognition, and action. But the existence of latency and sensorimotor discrepancies can hinder the communication. The latency of time lag between the user's action and the perception of the consequences of that action realises through sensorial interfaces. The quality of the VR application is assessed by the lack of latency and sensorimotor discrepancies. It is obvious that sensorimotor discrepancy is an unavoidable phenomenon, as no matter how many sensory channels are used in an application, the behaviour of the subject always respects the real-world situations.
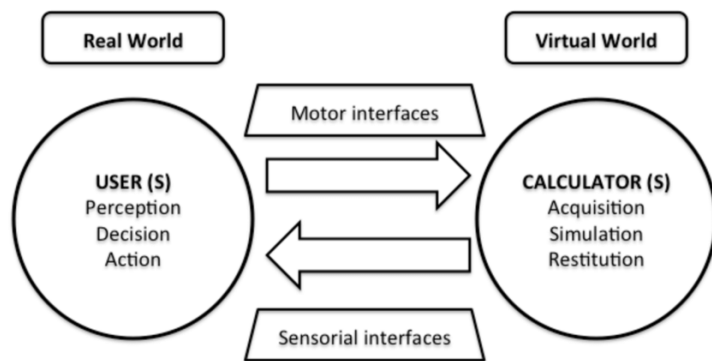
Figure 5 Diagram showing the issues of virtual reality, based on the "perception, cognition, action" loop (Fuchs et al., 2011).
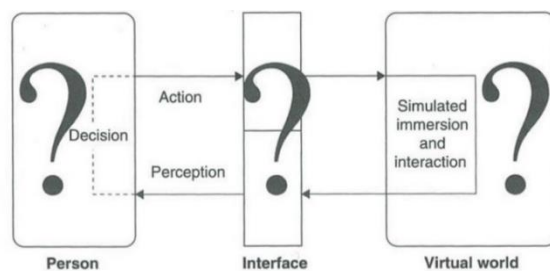
Figure 4 The "perception, cognition, action" loop going through the virtual world (Fuchs et al., 2011).

Therefore, the fundamental issues of VR are based on the "perception, cognition, and action" loop, through which a participant perceives, decides, and acts in the VE with the help of virtual application (Figure 5).

4.1.1.1 Mixed Reality Continuum

Schnabel (2009a) articulates a theoretical position of seven types of reality. They are in sequence: Real Reality, Amplified Reality, Augmented Reality, Mediated Reality, Augmented Virtuality, Virtualised Reality, and Virtual Reality (Figure 6). Amplified Reality means amplifying properties of physical objects with the help of computational means. Augmented Reality (AR) adds virtual elements to the perceived reality and allows interaction in a real-world environment. AR deals with how the user perceives reality, while Amplified Reality influences how the perceived reality is made available to the user. Mediated Reality explains the general concept of the artificial modification of human perception by re-synthesising the information by addition or removal from the scene before it is 'seen.' Augmented Virtuality describes the concept of looking into reality from a virtual world perspective. Virtualised Reality describes the means of communicating reality or scenes of real events by capturing scene descriptions from several viewpoints in the VE. The other end of the Reality-Virtuality continuum, VR defines an entirely computer-simulated environment. VR is a constructive tool that aids the designer in the act of designing and communicating within a virtual realm. Here, the designers explore a design without the need for a real artefact. Schnabel argues that VR is elaborately used in Architectural Engineering and Construction (AEC) projects but seldom used for designing itself, such as creation, development, form-finding, and collaboration. This is due to the challenge faced by designers to manage perceptions of solid and void, and navigation and function. VR facilitates designers to communicate, investigate, and express their imaginations with less effort. The IVE presents new opportunities and answers to design problems through active and real-time interactions with 3D artefacts. One can change viewpoints and escape gravity, while remaining within the design. However, even having such

advantages, a translation of design and information from VR into other realities is admittedly problematic.
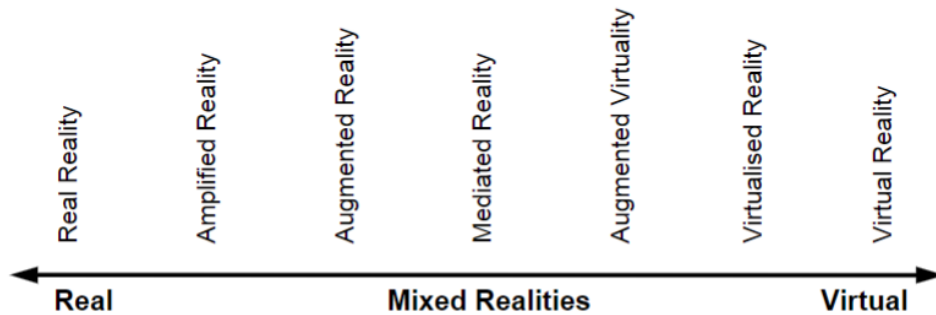
Figure 6 Order of reality concepts ranging from reality to virtuality (left to right) (Schnabel, 2009a).

4.1.1.2 Technological Attributes of Virtual Reality Devices

Head-Mounted Displays (HMDs) are the main hardware component of a VR experience (Nite, 2015). Currently, different brands like Oculus Rift, Valve, HTC's Vive, and Gear VR are making VR experience affordable for consumer use. HMDs allow a large field of view to encompass the user's entire normal vision range. The HMDs from Oculus Rift currently have a 100 degree field of view, whereas the human field of view is approximately 120 degrees binocular vision. This attribute allows users to forget that they are wearing a device and become immersed in the VE. The display develops using stereoscopic 3D by projecting separate images on each eye, imitating the way our eyes actually receive information. It allows the users to get the true 3D depth perception of the VE. The user's vision moves with the same rate equivalent of the user's head movement with a VR headset. This feature allows one to look around in the VE in the same way the user would look around in the real world. This was impossible in earlier versions of VR devises without causing motion sickness due to lag. However, now, with advanced technology, we can trick the mind into accepting this kind of motion as reality. This happens due to a combination of low persistence displays and a high refresh rate, effectively reducing and potentially eliminating motion sickness by removing motion blur (Nite, 2015). It produces 90 frames-per-second (fps), which is faster than our eyes can consciously perceive and also potentially faster than our subconscious perception. All these factors avoid

the effect of motion sickness. Moreover, the HMDs obtain a head tracking system via a separate camera or laser scanner mounted in front of the user, which helps to track a user as an avatar in a multiplayer environment. Nite states a conceptual equation on achieving presence in a VE:

> *Fast refresh rates + accurate head tracking + true 3D (stereoscopic) = VR that can achieve presence*. (Nite, 2015, p. 5)

4.1.2 Concept of Sense of Embodiment in Virtual Reality

Kilteni et al. (2012) provide a working definition of sense of embodiment in three individual sub-components: the sense of self-location, the sense of agency, and the sense of body ownership. First, the sense of self-location refers to sensory evidence of self-localization inside the VE. It is highly determined by the visuospatial perspective, which is usually egocentric. The importance of egocentric visual perspective for self-location is based on a sense of self-presence in the VE. The person can inhabit the environment as an avatar body, whereas the analogous feeling of presence would be the feeling of one's self-being located in a virtual room. The tactile input also influences self-location as the border between our body and the environment is our skin. This is due to our brain encoding differently to the spatial proximity to the body. According to this criterion, there are three different spaces that surround our body. Personal space is the space our body occupies, peri-personal space is the space adjacent to the body that is within arms' reach, and extra-personal space is the far non-reachable space. In existing head-mounted VR experience, the extra-personal space becomes non-real and easily navigable in the VE.

Second, the sense of agency refers to the sense of having "global motor control" through the subjective experience of action, control, intention, motor selection, and the conscious experience of will. Agency acts in the presence of active movement. The presence of synchronous coordination of movement and visual perception by the brain under active movement allows one to feel oneself to be the agent of those actions. Here, the embodiment of tools is under the control of the users.

Finally, the sense of body ownership refers to one's self-attribution of a body. The concept implies that the body is the source of the experienced sensations. The sense of body ownership emerges from sensory information that arrives in our brain from our sensory organs.

4.1.3 Concept of Interactions between Virtual Reality and Behavioural Sciences

Behavioural Science researchers make use of experimental devices associated with VR with the intention to use the sensory information and the control conditions of the activity possessed by the subjects to better understand the sensory, motor, and cognitive determinants (Mestre et al., 2011). This indicates that the embedded system of VR is developed through a dialogue between Engineering Technologies and Behavioural Sciences (Cognitive and Sensorimotor). The objective of VR systems is multi-dimensional in nature, which cannot be solved by system designers completely. It is necessary to establish a good connection of interaction between Behavioural Sciences and VR. This refers to the principle of collaboration. The "behavioural" approach of VR can help to bring about significant advances with an efficient VR system. In the current state, the VR is no longer about considering a technological element, but as a result of the interaction of human with devices. The experiments possible in VR are limited by the sensory cues and the interactions that can be reproduced. However, it is necessarily limited concerning that which is possible in the real world. VR claims to bring the real world into the laboratory, which gives it more power, and behavioural science is helping to systematise the development of VR technology.

During a VR experience, which activities the user will perform can be understood through behavioural activities. These can be referred to as Virtual Behavioural Primitives (VBP) (Fuchs et al., 2011). The VBP can be grouped into four categories:

- Observing the virtual world;
- Moving in the virtual world;
- Acting in the virtual world;
- Communicating with others or with the application for its control.

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In the first categorical virtual experience, the subject is almost always "technically" passive in the VE, as he or she does not use the hardware device to search for the sensory information in the VE, except in some cases where eye trackers are used to determine motor activity during eye movements. Human perception is not a passive activity but is often connected to motor activity, like the ocular movement of the eyes observing a scene. Some researchers are also pushing to add tactile experience using touch-sensitive interface that detects the movement of the user's hand. In the other three categories, the subject is always active in the virtual world as he or she interacts with the environment. The performance of the subject varies in three VBPs according to the differences of hardware and software solutions, which are commonly known as "the interaction techniques." These four categories are cognitively linked through Fuchs et al. (2011) loop of "perception, cognition, and action."

4.1.4 Perceptual Understanding in Immersive Virtual Environment

IVE gives the experience of sensed reality in virtual environments. It helps the user to perceive some volumetric qualities of a building or space, which are hard to depict in 2D drawings. It develops an artificial environment that imitates real-world surroundings convincingly enough that the users suspend scepticism and fully engage with the created environment. IVE offers an active and real-time interaction with the design, therefore presenting an authentic feeling of being in the environment. It has been proven that the qualities of design and the designed products are directly linked to the nature of the communication and collaboration that has taken place during the design process (Schnabel & Kvan, 2003). IVE's three-dimensional (3D) medium leverages users to create, communicate, and collaborate during the design process. It already has shown significant contribution in the field of architectural practices for design communication with stakeholders. Design communication during the design process plays a substantial role in the exchange of messages and ideas between people with different skillsets and interests. Using visualisation during this process provides an effective way to communicate information, thus generating more creative ideas.

Moreover, psychology studies indicate that there is less cognitive load on the brain in VE than a normal flat screen with a comparative experiment between 2D/3D non-immersive and 3D immersive scenarios (Kozhevnikov & Dhond, 2012). Hence, it has been proposed that 3D IVE potentially creates a more natural environment for the brain in qualitative building simulation, as compared to the conventional 2D screens (Hermund et al., 2017).

Also, Chan (2011) argues with a comparison that IVE can provide visual perception with more content and meaning than other senses; it more easily triggers the sense of presence. In IVE, the sense of presence experienced in the environment results from cognitive processes. The sense of presence is generated from human senses of light, sound, taste, smell, and touch. In a VE, three conditions are required to create a sense of presence through perceptions: image quality, image dimensions, and view distant. There are several articles that argue that high quality or resolution of images, large scale or dimensions of images, and the closer distance between viewers and images produce a greater sense of presence.

4.1.5 Design Communication and Representation

We know the difference between the idea of design and its representation, communication, and realisations. Architects and Urban Designers use a variety of tools to bridge this gap. Each tool offers different options to the designer to afford, introduce, and reinterpret different design ideas (Schnabel, 2009b). In such a case, the unique properties of IVE(s) can empower designers to express, explore, and convey their imaginations more easily (Schnabel, 2011). That is the reason IVE can allow designers to create novel designs that make use of additional properties that conventional 2D realms cannot offer. Schnabel's research proves that IVE aids effective conduction in design creation and communication of architectural spatial design. Also, Schnabel (2004) in his thesis elaborates the benefits and representation of design within different media, and reports description of contribution to the initial design development stage. His work is an extension of Kvan (1999), which describes the importance of different media in initial design

communication. Their research has been discussed more elaborately in the next chapter, Chapter 5.

According to Schön (1983), design processes are reflective ones. Designers always adjust media information to map the internal representation with the external information. Designers' cognitive activities are constantly converting the abstract internal representations into external ones by continuously transforming mental data into an external form. Chan (2011) also argues that different designers use different problem representations across different media. Representations created in VEs differ according to the associating reality. If the design conducted in the VEs is a real-world problem dealing with generating artefacts to address certain issues of reality, then the representations used are mental images mirroring the realistic images reflected from perception. On the other hand, if the design is just a creation of artefacts and not a real-world problem, then the representations created are arbitrary images coming from imaginations.

The relationship between two-forms of representation like verbal-conceptual and visual-graphic facilitate the formulation of a mental representation of a design idea as well as communication of design ideas (Gül & Maher, 2009). This is because the designer relies on techniques of design representations not only to communicate ideas to them, but also to others. Design representations enable a dialogue between the designer and her/himself as well as others.

In the field of architecture design, the design processes choose design information given by the clients or information gathered through research on the project functionalities (Chan, 2011). These pieces of information ultimately become the design constraints for developing design strategically, considered as the first layer of design information. Design strategies are developed next, based on the selected design requirements and functionalities. Designers will create their own personal design constraint methodology to meet the functional requirements, and sequentially, designers will draw from memory to generate a solution. Such design ideas, which might be images, diagrams, or abstract concepts, are created in designers'

mind's eyes, known as internal representations. These internal representations are the results of cognitive operations that turn the design information into concepts. The data that symbolizes the cognitive processes constitutes cognitive information.

After developing the design concepts as internal representation, the designers apply certain procedures through selected media to make them visible. Different media has a different operational world with unique methods of operation. They require different algorithms or procedures for operation. These different algorithms or techniques define another layer of media information. If the media is the pencil-and-paper mode, then the designer has to have drawing skill. If the media is computer software, then it is essential to know the functions to create 3D forms or shapes. Again, if the media is film or video, then it is necessary to understand the syntax of composition and the semantic language of film production. In VR media, it is reliant on the format of the virtual models in order to make them accurately displayed in 3D stereoscopic mode. This media helps to generate some external representation of a drawing, video, physical model, digital model, virtual model, or a combination therein.

4.2   Collaborative Design in Virtual Environment

This section discusses briefly digital-supported design collaboration, the concept of co-design, and perceptual awareness in a collaborative virtual environment.

4.2.1 Digital-Supported Design Collaboration

Digital-supported design collaboration inspires different types of strategies through which designers can constructively share their differences and environments in search for a common goal that is beyond individual vision (Idi & Khaidzir, 2018). In architectural design practice, digital-supported design collaboration implies the implementation of a Building Information Modelling (BIM) system. The major barrier to the successful integration of digital supported collaboration is the rigidity of team problem-solving of the digital modalities. The flexible nature of a conventional method keeps this

new approach obscured (Oxman, 2006) due to its rigidity to support cognitive design activities. By contrast, there are other researchers who argue that digital modalities and collaboration can enhance conventional building design practice (Froese, 2010; Garber, 2014). However, insufficient effective digitization and collaboration in the conventional design process significantly affects quality, efficiency, and productivity. Digitisation and collaboration during design stages are the ultimate contemporary catalysts that can enhance building design processes (Bryde et al., 2013).

Development of computer-mediated and communication tools for collaborative design corresponds to the coding and modelling of the content (Gabriel & Maher, 2002). The prime concern in developing computer technology for design collaboration is to have a better understanding of the way the collaborators think and work. Rahimian and Ibrahim (2011) analyse impacts of VR 3D sketching on novice architectural designers' spatial cognition in collaborative design and argue that such haptic-based sketching technique interfaces can improve designers' cognitive and collaborative activities. They in their another article argues that CAD tools have advantages for detailed engineering design, but hinder the creativity of novice designers in collaborative design (Ibrahim and Rahimian (2010).

4.2.2 Concept of Co-Design, Awareness and Artefacts

Co-design or collaborative design is a term to define a process of designing where different parties like designers, architects, engineers and sometimes clients work together to achieve a shared design goal (Gül, 2020). They work together on a design artefact or parts of it. Co-design process is similar to an individual's mental process which establishes shared goals and develops a shared understanding of design brief, searching through design precedents for inspiration, defining design constraints, framing and examining design problems, and the materialisation of a design solution. In a "co-located" situation, architects or designers are located in the same room allow natural verbal and visual communication between parties. The effectiveness of visual communication depends on both "shared representations" and a shared workspace. The term shared representation means all types of external

representations that architects or designers rely on for communicating design ideas through artefacts like sketches, physical or digital models, diagrams, graphs or notations. In a co-design approach, external representation plays a significant role to interact with the artefacts. When design thoughts are externalised through artefacts, each artefact contains properties for future interpretations that designers can negotiate during further design development. Artefacts those can be pointed to, talked about or sketched on (Perry & Sanderson, 1998) play an important role both in conversation with oneself and with others. Also, these external representations become the ground for conflicts and collaboration. Arias et al. (2000) argue that externalisations are important for two reasons 1) to create a record of mental efforts; one that is "outside us" rather than a vague memory and 2) represent artefacts that can talk back to us.

Studies have shown in co-design situation that the process of collaborative negotiation and evaluation depends on the expertise of the designers (Gül & Maher, 2009; Kvan et al., 1998). During co-design, designers want to become aware of each other's activities. Being unaware of others' activities would break the flow of co-designing. Gutwin and Greenberg (1998) argue, in co-design, the workspace awareness is important for two reasons, one is the amount of power it provides to the user and second is its degree of visibility to rest of the group in collaborative work. Workspace awareness can be achieved in two ways: "consequential communication" and feedback. The consequential communication allows the characteristic movements of an action to communicate its character and content to others (Gül, 2020). And feedback is produced when artefacts are manipulated and provides clues of that manipulation to others (Dix et al., 2003).

4.2.3 Concept of Co-Design in "User-Centred Design" Approach

The term 'co-design' also coincides with the definition of participatory design. It defines the user-centred and empathic design approaches. In the world of product design, it is commonly used to put the end-users in the centre of the design process and to include their needs and interests.

In the 70s, along with the emerging approach of participatory design in the Scandinavia region, it was believed that ones who were affected by design should have an opportunity to influence the design. Sanders and Stappers (2008) show the differences between user-centred design as 'user as a subject,' and participatory design as 'user as a partner' (Figure 7). The concept of 'user as partner' represents the same concept of 'co-design'. Thus, in the Nordic region, participatory design most often used the synonym 'co-design.' Participatory design is considered as design with a special focus on people participating in the design process as co-designers.
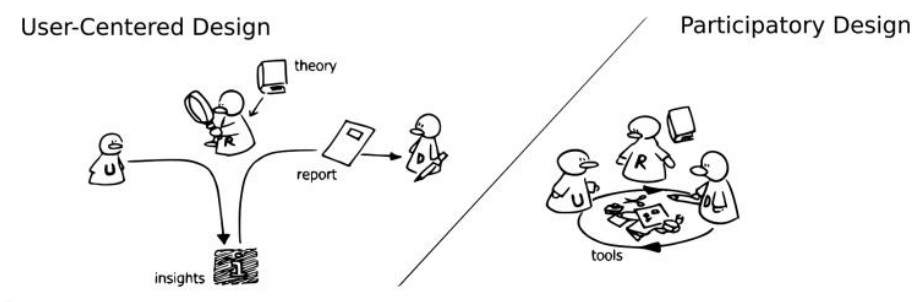
Figure 7 Visual representations: UCD on the left and PD on the right (Sanders & Stappers, 2008).

Mattelmäki and Visser (2011) describe four directions of co-design as participatory design (Figure 8). Direction A emphasises the role of a user as a one direction communication where the user's voice needs to be heard. This direction is not co-design, and that is why this approach is used a lot in the field of urban design and planning. In direction B, users are designing ideas that are just inspiration for ideas, while in direction C the users and designers exchange ideas and envision a collaborative creation process. The last
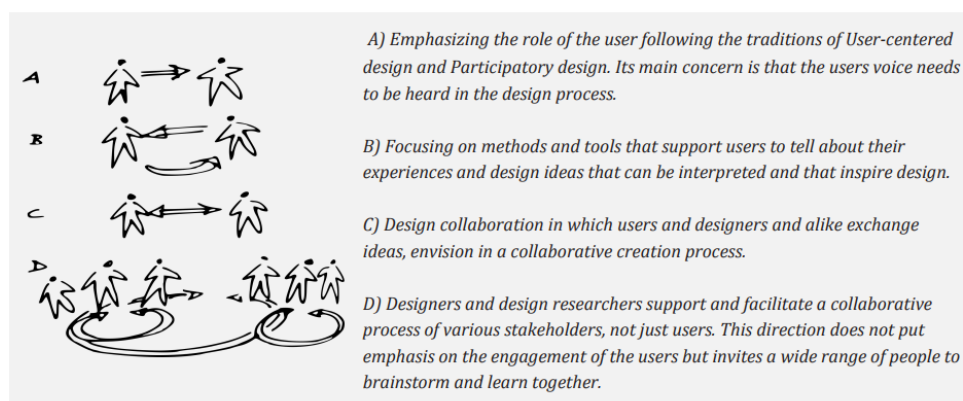
Figure 8 The four Co-design directions (Mattelmäki & Visser, 2011).

direction, direction D, facilitates collaborative processes with various stakeholders; not only users, but also a wide range of various stakeholders, are able to brainstorm and learn together.

4.2.4 Perceptual Awareness in Collaborative Virtual Environment

Perceptual awareness is an important factor in IVE design collaboration, as evidenced in ethnographic studies (Maher, 2011). This is because independent participants in the collaborative design process need to be able to coordinate and inform their activities through background or peripheral awareness of one another's activities. So, Collaborative Virtual Environments (CVE) provide new ways to meet communication needs when negotiation is important and frequent. An important aspect of collaborative design is that the focus of the meeting is on the design ideas and models rather than only discussion between designers. It is necessary to develop a shared understanding of the design problem and potential solutions. However, communication among the participants in the environment allows individuals to pursue their own tasks as well as to focus their attention on a shared task. Also, studies report that designers move fluidly from working individually to working together when engaged in virtual collaborative design.

The affordance of peripheral awareness for collaborative design is explored and documented in research by Gül and Maher (2009) in the article on co-creating face-to-face sketching and designing in VEs. The research develops a coding scheme to analyse different modes of interactions through external representations to assist design collaboration. The article refers to external representations of drawing sketches and digital models. The encoded protocol represents the context of collaborative designing, how designers collaborate and communicate, and what kind of interactions they have with the design representation. The study aims to characterise the collaborative design process when designers are using traditional materials—pen, paper, scale, etc.—and with digital systems for designing and communication. The comparison study is done in three collaborative design sessions: face-to-face with remote sketching, face-to-face with a 3D virtual world, and face-to-face

with 3D virtual world sketching in a fixed period of time on similar design tasks. The participation of the designers is video recorded with the conversation. One of the results of this study showed that in a remotely located virtual world, the designers are able to move from meeting mode to individual work mode while coordinating with their collaborator. It also reports that the designers conduct continuous actions while they are designing in the 3D modelling environment with more detail in the co-created representation. The study ends by stating that the developments in collaboration and design technology are encouraging designers to consider new media for communication and designing. The cognitive impact of CVE on designing must, therefore, be addressed. It also suggests that the analysis of the collaborative design protocols provides a basis for a better understanding of the interactions with different representation techniques. The authors speculate that the acquired knowledge has implications for both developments in future CVEs and choosing an appropriate medium for designing. However, the study does not explore the possibility of design collaboration when immersed in the VE, where the cognitive load is significantly less to perceive.

4.2.5 Affordances of Virtual Worlds for Collaborative Design

According to Marshall McLuhan, "media are the extensions of mankind," so the perceptual affordance of digital media has made significant contribution to virtual design collaboration. Koutsabasis et al. (2012) investigate the value of VWs affordances and tools that can contribute to collaborative design projects that involve designers' cooperation and client feedback. The affordance of VWs are exploited to foster collaborative activities in various stages of design: communication, embodiment, presence and co-presence, 3D visualisation and interaction, and increased user engagement, as well as all of the above. Despite the increasing interest in exploring the affordances of VWs as a platform or 'tool' for mediating collaborative design activities, design studies in VWs are still scarce. This is because the design community still shows interest in pragmatic uses of technologies in existing practices. However, the value of VWs for collaborative design activities can contribute to the phases and activities of authentic collaborative design projects that

involve designers' cooperation and client feedback. The design community has not accepted Collaborative Virtual Environments (CVEs) for their everyday work, possibly because of the high cost of immersive hardware, and the limited availability of generic software platforms for immersive VR applications combined with the amount of time and money needed to develop customized solutions.

4.3   Concept of Design Decision-Making in Virtual Environment

Design decision-making is a vast field of research. My research only addresses a subset of design decision-making specific to visual perception. Visual perception depends on the provided information and on the receptors to bear the cognitive load of that information in VE. When a designer is making a decision in VE, the instrument should provide effective transmission of information and enable the individual to process the information. The instrument that enables greater re-processability, repeatability, and a high degree of parallelism is more appropriate for conveyance processes.

The current phase of virtual design tools is not only allowing designers to analyse and evaluate, but also generate and explore alternative design proposals. We have already explored design evaluation using the 3D interactive interface on a VE or IVE, which are more effective than looking at regular 2D drawings (Milovanovic et al., 2017; Schnabel, 2011). These claims are based on the quality of the visual information, which is supporting designers to make effective design decisions. These are due to enough cognitive load in an IVE. In addition, Schnabel (2011) experiment shows that participants admitted that working in IVE enabled them to deal with design complexity that was superior to their design skills.

Developing conceptual models for civic engagement requires us to deal with issues of rational ignorance to come into consensus in a short period of time (Poplin, 2014). Organising civic engagement in a way that can enable the citizen to become immersed or involved in design situations to the point

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of "being there" brings the sense of walking in the space while discussing it. Greater citizen involvement in the virtual decision-making process is needed to deal with complex urban issues (von Heland et al., 2015). The audience has to relate to the proposal. The result will be useless with lack of engagement and connection. The outcome of the participation is not predictable, and at the end of the process, it is counted as the result of the activities by a group of stakeholders. So, in this case, one single voice cannot change the situation.

On a related note, Mitchell (1995, p. 5), in his seminal "City of Bits," proclaims that:

> *The emerging civic structures and spatial arrangements of the digital era will profoundly affect our access to economic opportunities and public services, the character and content of public discourse, the forms of cultural activity, the enaction of power, and the experiences that give shape and texture to our daily routines. Massive and unstoppable changes are underway, but we are not passive subjects powerless to shape our fates. If we understand what is happening, and if we can conceive and explore alternative futures, we can find opportunities to intervene, sometimes to resist, to organize, to legislate, to plan, and to design.*

This statement suggests the need for exploration of how digital technology can be used in shaping our future city design endeavours; and particular to the context of my research, how digital technology can be employed in the urban design decision-making process.

4.4   Concept of Coding in Communication and Protocol Analysis

Donnellon et al. (1986) draw an interesting point: that the minimal degree of shared understanding need not be conscious or verbalizabled; it can be a repertoire of behavioural options that members of a given society can recognize, respond to, and use to interact with one another. This repertoire of communication mechanisms is the means through which people collectively

develop interpretations of their experience. Despite apparent differences in the interpretations of those behaviours, shared forms of communication forge some agreements. To identify the shared forms of communication, Donnellon et al. (1986) proposes semantic coding of the transcription of interaction that could be found after a recording. This also helps to identify shifts of interpretation of the events and members' inclinations towards specified actions. He also proposes linguistic analysis to examine the sequential and multi-level communication behaviours associated with the action of the members. He concludes the article with a proposition that in the communication process, meaning and action are related in a complex iterative process in which meanings are continually constructed and destroyed as more sense-making communication occurs and new actions are taken.

Basically, protocol analysis with a coding scheme is used to identify different design activities, and reveal different mental models and the knowledge structures of designers. In general, protocol data is based on samples of observations that are mainly qualitative (Kan & Gero, 2017). It refers to a set of methods for obtaining reliable information about what people are thinking while they are participating in a task. The importance of protocol analysis is to understand the design process, as it helps to reveal the traits of design thinking between action and perception (Goldschmidt, 2014). It is an empirical research method to investigate the cognitive behaviours and thinking processes generally adopted by problem solvers (Akin, 1986; Ericsson & Simon, 1993). Ericsson and Simon (1993) developed the foundation of using verbal protocols and concurrent reporting as quantitative data to examine the thought process. In a collaborative design process, it is impossible for individual members to think out loud; however, they support Cross et al. (1996, p. 3) statement that "*the verbal exchanges of members of a team engaged in a joint task seem to provide data indicative of the cognitive activities that are being undertaken by the team member.*" As Kan et al. (2011) state, many researchers choose to use protocol analysis techniques to study design collaboration. They mainly focused on verbal communication as a form of talking aloud, and considered the raw protocol data. The concept of 'thinking loud' during problem-solving means that the subject keeps on

talking, speaking out loud while performing the task at hand (Van Someren et al., 1994). This method does not lead to much disturbance in the thought process. The subject solves a problem while the talking is executed. The subject does not give an interpretation of his or her thoughts. The protocol is not necessarily complete because a subject may verbalize only a part of his or her thoughts. It is also accepted that protocol analysis has limitations in capturing the non-verbal thought processes during the design process and, therefore, important non-verbal communication is often neglected.

4.5 Concept of Perceptual Affordance and Designing Communication Instruments

The interaction with the design instruments depends on the perception of the users, and the perceivable using opportunities offered by the instruments (Gaver, 1991). That perceivable using quality known as "affordances". In Gaver's word *"when affordances are perceptible, they offer adirect link between perception and action".* To develop a design based instruments, it is nessary to understand the capabilities and limitations of instruments in order to know the possibilities they offer for design. In this section, I discuss elaborately the concept of perceptual affordances and the designing communication instruments.

4.5.1 Concept of Perceptual Affordance

Psychologist James J. Gibson was the first who brought the affordance theory ("Learning Theories," 2016). Affordance theory states that the world is perceived not only in terms of artefact shapes and spatial relationship but also in terms of artefact possibilities for action (affordances)-perception derives action (Gibson, 1966). According to the theory, people perceive the environment directly in terms of its potentials for action, without significant intermediate stages of involving memory or inferences. For instance, people perceive stairways in terms of their "climbability", which is a measurable relationship properties between people and stairs. Affordances are a relationship as a part of nature: they do not have to be visible, known, or desirable (Norman, 2008). Gibson conceptualised the theory following with

physical actions, so that his original meaning may now perhaps best be described as a "physical affordance" (Overhill, 2012).

Gaver (1991) extends the concept as artificial or designed affordances in drawings and illustrations, which convey functionality through graphic representations of the designed features. As examples buttons for pushing, knobs for turning, handles for pulling, levers for sliding, etc. That means the users do action by perceiving the opportunity offered in the artefacts. He argues, "*affordance per se are independent of perception*" (p. 80). In interaction design, affordance represents the properties of artefacts that show the possible actions for users to take with it, thereby suggesting a way of interacting with that object ("The Interaction Design Foundation," 2019). The attributes of affordance exist with or without the perceiver's cares. For instance, a glass of water affords to drink whether the perceiver feels thirsty or not. It is an inherent property of the artefacts that they need to be perceived. The perceiver takes action according to the perceived quality of the affordances from the attributes of the artefacts. It is not necessary to act upon what is perceived. From this point of view, different digital media makes different perceptual information act differently. "*The actual perception of affordances will, of course, be determined in part by the observer's culture, social setting, experience and intentions*" (p. 3). So, the concept of affordances points to the configuration of properties of the artefacts. It applies to not only the physical attributes of the artefacts but also the information of the attributes that are available in a form with a perceptual system, and the actions are relevant to the perceiver.

Norman (2008) describes the concept as "perceived affordance", which is fundamentally different from the original meaning of Gibson's "physical affordance". According to Norman, in product design, the term "perceived affordance" explains what the user perceives than what is actually true. Designers care about is whether the user perceives that some action is possible or not. Designers dealing with physical artefacts the perceived affordances are real, but in graphical or screen-based interfaces, designers have available control over perceived affordances. For example, in a computer system, the keyboard, display screen, pointing device such as

mouse and it's affords of pointing, touching, looking and clicking has no value till the users perceive it. So the perceived affordance is independent; it depends on the offered functionality of the system. Figure 9 shows a conceptual framework of artefacts' perceptual affordance to the users. Users perceive an artefact either through sequence of actions and perceptions or by the environmental clue offered by the attributes of the artefacts.
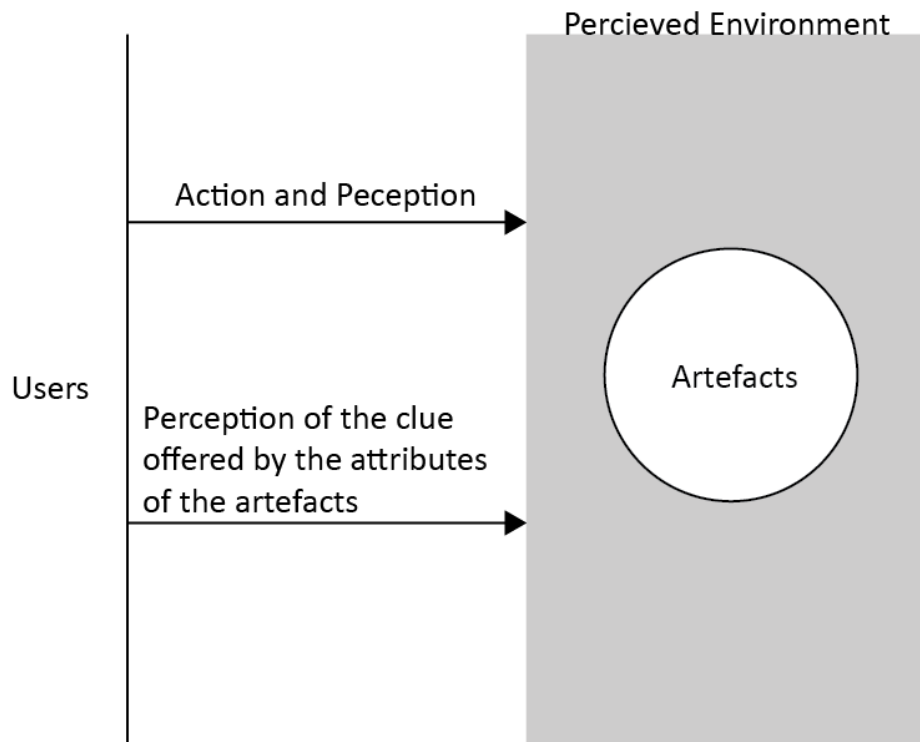
Figure 9* Artefacts perceptual affordance to the users.

In digital media, the affordances of the artefacts mediate in the interface to allow for a certain action. Interfaces offer perceptible affordances as they offer information that artefacts act upon. For instance, various graphical techniques allow us to perceive the 'pressability' of an onscreen button, which directs us to a certain type of action. The notion of affordances also extends to the scope of exploration. In the case of computer interface, a button may lead to visual information about its affordance of dragging, which reveals new instantaneous affordance through the action of dragging. Gaver (1991) calls this phenomenon of revealing affordance as sequential affordances. The perceiver reveals the attributes of the artefacts over time by

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sequential actions. The role of a good interface is to guide attention via well-designed sequential affordance. The notion of affordance brings the factors of perception and action that make interfaces easy to learn and use. Gaver speculates that considering affordances explicitly in interface design will improve the usability of new artefacts. He concludes with a valuable way to think about transparent interfaces. It encourages us to consider devices, technologies, and media in terms of perceived and acted actions. His concept can guide us in designing artefacts that emphasize desired affordances and de-emphasize undesired ones.

4.5.2 Designing Communication Instruments

Sanders et al. (2010) argue that the instruments and techniques are used to involve non-designers in the participatory design process differ projects to projects. As the participatory design process involves people having different backgrounds, experiences, interests, and roles, so an important challenge is to find appropriate ways of engaging and involving non-designers in design activities. It is very important to understand the purpose and context of the instruments and techniques as well as the user's experience. Getting access to the user's experience can help the designers to design the communication instrument (Sanders, 2002). "*If we can access what is being communicated and what experiences are influencing the reception of communication, then we can design for experiencing*" (Sanders, 2002, p. 2). There are different routes to access the user's experience, and each of them reveals a different story (Figure 10). It includes people's saying, thinking, doing, using, knowing, feeling, dreaming and so on. According to Sanders, saying and thinking count as explicit knowledge as they are able to be expressed in words. Watching what people do and seeing provide observable information as observed experience. Discovering what people think and know helps us to perceive their experience. Seeing and appreciating what people dream shows us how their future could change. These give us the ability to reveal latent needs, which are not recognizable until the future. This knowledge is tacit knowledge, as that experience can not readily be expressed in words. When all three perspectives of experiences (what people do, what they say, and what

they make) are explored simultaneously, then one can more readily understand and establish empathy with these people. So, through designing a communication tool, a designer facilitates active design participation of non-designers as the tool can address what they say, think, do, know, and dream.
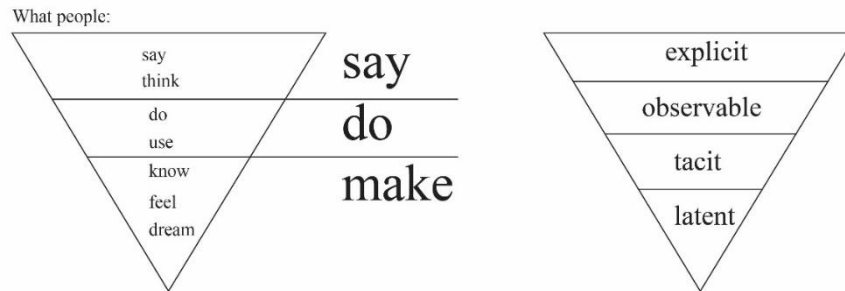
Figure 10 left What people say, do, and make; right Levels of need (Sanders, 2002).

4.6 Summary

The quality of communication and visualization in a VE is at the heart of any design discussion. VR is a tool that aids the designers in the act of designing and communicating in a VE (Schnabel, 2009a). It allows designers to communicate, investigate, and express their imaginations with less effort. Through the evolution of computing power, now designers can explore design in a VE with 3D artefacts instead of real artefacts.

The representation of 3D artefacts in a VE allows designers to initiate new design ideas. It supports the urge to get a direct and constant perceptual understanding of spatial consequences, which Gaver (1991) refers to as the quality of perceptual affordance. VR can facilitate design discussion on the spatial features of urban forms as 3D artefacts. VR techniques simulate through imitating representation (Lister et al., 2008) of the certain urban situation. A higher level of sophistication could be achieved in an IVE experience, where the sense of reality occurs within a volumetric space. It supports an active and real-time experience with the design, therefore presenting a sense of being in the environment. One of the advantages of IVE is that it carries a less cognitive load to the participant, as the participant inhabits the immersive environment.

Moreover, VR with immersive features provides a certain degree of interaction (Lister et al., 2008). The pleasures and the modes of consumption happen through the act of seeing and the operation of vision. The features of VR also can be seen as a technological extension of the body and its senses (McLuhan, 1964). In detail, the sense of embodiment in VR varies by the sense of self-location, the sense of agency, and the sense of body ownership (Kilteni et al., 2012). The sense of self-location is egocentric and depends on visuospatial perspectives of personal, peri-personal, and extra-personal space. In a VR experience, the extra-personal space becomes non-real and offers easy navigation in the VE. Due to the sense of agency, the user becomes active in the VE. The sense of body ownership refers to the sensorial interaction with the VR tools. In brief, the concept of sense of embodiment depends on the level of presence in human engagement.

As an experiential tool in VR, HMD allows the user to get the true 3D depth perception of the VE (Nite, 2015). The display uses stereoscopic 3D by projecting separate images on each eye through accurate head tracking. It allows looking around in the VE in the same way the user would look around in the real world. To achieve this sense of presence in a VE, a fast refresh rate of the system and accurate head tracking with true stereoscopic 3D is required. An efficient feature of the VR tools permits the users to communicate with the peripheral understanding of the VE.

Besides, the quality of communication and visualization depends on the ability of the users to bear the cognitive load of that information in the VE. In a design process, the main puzzle that people face is how to make communication possible, which was once difficult, impossible, or unimagined. So, the design of the communication system is one of the crucial factors that determine the interactivity between designers and the instruments.

Understanding users' experiences through performance in the VR will help us to understand the interaction between the designer and the instruments. The interaction between Behavioural Sciences and VR refers to the principle of collaboration (Mestre et al., 2011). During a VR experience, the users' performance can be understood through the behavioural actions of

observing, moving, acting, and communicating with others or the tools. The actions related to observing in the VW are passive but depend on motor activity of ocular movements. The rest of the three behavioural actions are active as they interact with the environment. This interaction of users' behaviour also refers to the transposition between perception, cognition, and action (Fuchs et al., 2011). It is necessary to have a seamless flow in the operation of the virtual instruments; then it can facilitate more successful design interaction without the latency of time lag between the user's action and the perception of the consequences of that action in the VE.

To understand the shared form of behavioural interaction in VE, there are studies which discuss protocol analysis is an effective process. It reveals different mental models and knowledge structures of designers while they are participating in a task. Recording verbal protocols as qualitative data for coding examines the thought processes sequentially for multi-level design communication. It acts as a repertoire of behavioural options in a shared understanding of design actions. Thus, my research also employs a technique of protocol analysis to code design conversation in VE.

Chapter 5 Precedents

This chapter compiles other researches to show that most of them did not engage with real world context. I explain my arguments regarding why I haven't used their proposed systems as well as methodology. The chapter informs about the limitation of their research due to the lack of software compatibility and relevant know-how on how to offer comprehensive participatory engagement. The section clusters some recent projects under three themes: participatory digital design, iterative three-dimensional modelling as a decision support tool, and virtual-, augmented-, and mixed-reality in design collaboration. Every discussion starts with a description of the work and ends with the scope that the dissertation addresses. The study shows that there is limited evidence of laypeople's participation in virtual spatial design. Most of the research is in the ideation stage, which requires real-life exploration to report as evidence. In that case, my research destined to involve people in collaborative VE assisted participatory urban design setup in generating urban forms.

5.1   Participatory Digital Design

In this section, I discuss experimented and speculated digital participatory urban planning and design collaboration instruments. Some of them are used for design consultation and participation via the internet, some of them use a comprehensive VE setup to interact with multiple simulated urban dynamics, some of them use game-based 2D and immersive interfaces, and some of them tested as mixed-medium instruments for urban planning discussion.

5.1.1   Collaborative Urban Planning Platforms

One example of participatory digital design was the work of the city of Melbourne in 2007, whereby they initiated the 'Future Melbourne' project, which adopted an online platform for collecting comments and feedback from the wider community on the outcome of design consultation by invited stakeholders (Liu, 2017). They adopted an online wiki model where the public could read, edit, discuss, share, and contribute ideas about the drafted plan for future Melbourne. The platform adopted a rating system to extract the most popular design ideas. The whole plan was designed to get people's feedback on their future planning policy. Liu (2017) reports that this consultation process couldn't address all the people because of incompetence with the internet. Another drawback was the unlimited time to provide the answers: a person who was spending a long time giving feedback on one might ignore the possibilities of other ideas. So, most of the time, the collaborative feedback was happening on prefered ideas as opposed to all of them. Besides, the participants were providing feedback on the planning policy with limited shared experiences, where they could hardly achieve a perceptual understanding of the proposed environment. Also, they were not allowed to take part actively in spatial design decision-making.

Another example is the Swiss Federal Institute of Technology (ETHZ), which since 2006 has been developing a programme of work that deals with the information between citizens, urban design, and science for urban planning authorities. They developed several methods to ensure bottom-up participation of stakeholders using visual methods through analysis, design, and simulation of the urban system. Research conducted by

Cristie and Berger (2017) employed game engines to visualise scientific information like temperature, humidity, wind velocity, and direction through simulations (Figure 11). They argued that conventionally in architectural work visualisations are used as end products rather than as parts of the design. They proposed a design loop of simulation, visualisation, and exploration rather than a flow to achieve more iteration of the design process, which would provide new input parameters to the simulation. The research demonstrated how to create virtual exploration tools not only for buildings and environments, but also introduced how they could act as a bridge to connect stakeholders to urban science. The tools are expected to gain knowledge of 3D space and the data through discovery, personal experience, or collaborative exploration. This also explains how data could be segregated according to user needs without compromising visual or perceptual limitation by displaying too much information at once.
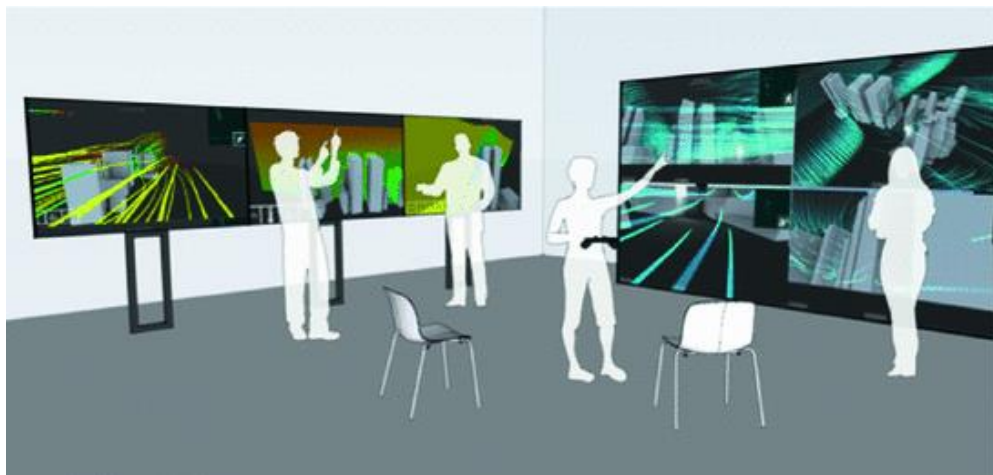
Figure 11 A collaborative multiscreen urban planning platform to engage stakeholders in design discussion (Cristie & Berger, 2017).

Though the research still needs to go through empirical studies, the presented scheme illustrated an impactful virtual platform for stakeholder collaboration. Their proposed platform does not consider any scope of manipulating the spatial arrangement of urban spaces. That means it does not have any features to reflect design actions. Also, it only evaluates the spaces in terms of quantifiable value with relevant attributes like wind, energy, and comfort, not the visual perceptual quality of individual interest as well as collective interest. The perceptual awareness of the proposed VE is also less significant compare to an IVE. Besides, the experiment does not show how

the participants make decisions in collaboration with stakeholders, which to some extent can validate the effectiveness of the system. The research does not discuss the perceptual and technological affordance of the instrument, which may require more expert knowledge to interpret.

5.1.2 Virtual Participatory Platforms

The virtual game platform *YouPlaceIT!* (Vemuri et al., 2014) brings a serious gameplay approach where each player takes a role in urban planning, such as residential representative, government, real estate agent, NGO, etc., and discusses an objective through online text chats and icons. In this case, a game serves as a common platform to encourage all related stakeholders to participate constructively in a dialogue about urban planning issues. The research aims to support complex urban design decision-making through consensus. The participants take relevant roles mirroring real-life stakeholders. The research aims to achieve a consensus through negotiation or financial trade-offs. Scoring is based on a rating of social interactions and financial status. The complex model lies in human behaviour motivated by perceptions, factual information, and financial implications. This is exemplified using a study case in Dharavi, Mumbai, India. The effectiveness of the game relies on the metric of transferring knowledge to the community stakeholders with the information required to make decisions in real-time scenarios. Initially, the game was GIS-based (Figure 12). Later it developed in 'Unity 3D.' The urban environment is based on the actual geographical area of Dharavi. The objects are residential structures of different types, utilities, industrial structures, schools, hospitals, benches, trees, and lights. However, this information is not in an immersive environment where the perceptual understanding would be much higher. The interactions among the players are enabled by multi-lingual text-chats and representational icons. There is no other way to generate representational artefacts via intuitive design actions. Such a gaming platform is a rule-based instrument that involves participants but limits the scope for design interaction. Although Vemuri et al. (2014) argue that online-based chatting can play a role in spatial order and identifying cultural differences between one social formation and the other, there is no shown analysis to support their argument. The research

still lacks a sufficient amount of data to support the effectiveness of the gaming platform. The advantage of employing a serious game is that it requires a fundamental understanding of the design situation and accommodates changes proposed by different stakeholders. Also, the proposed gaming collaboration happens in an online-based platform, where shared informal interaction enhances the quality of social discussion.
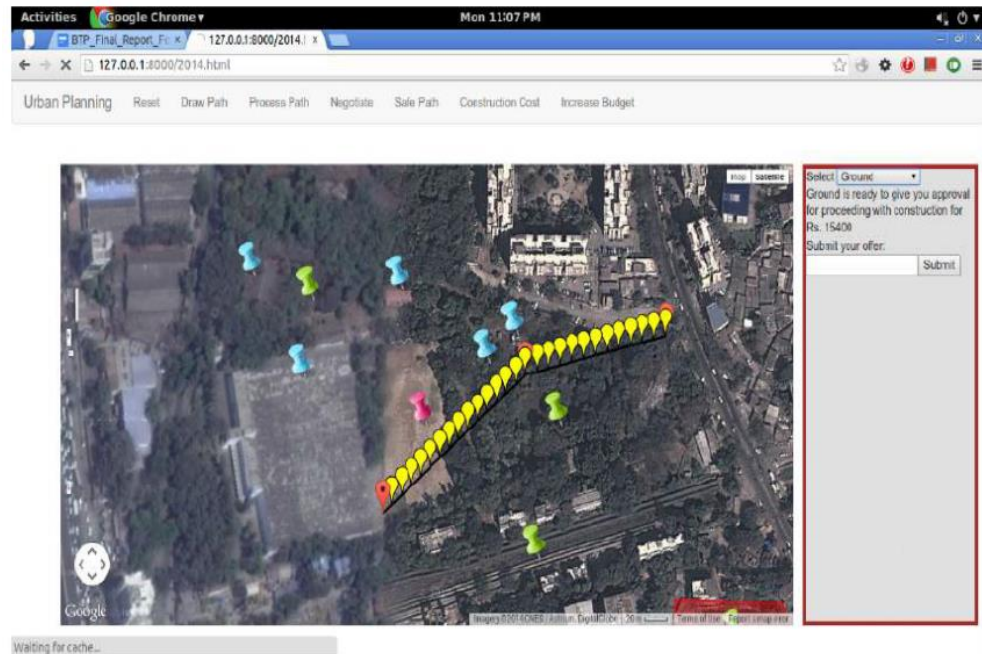
Figure 12 Screenshot shows negotiation process in Dharavai (Vemuri et al., 2014).

Similarly, Gordon and Schirra (2011) work in Chinatown engaged community people to play a role. Researchers, in this case, used a paper-based questionnaire and asked 48 players about experiences playing a game in a community planning meeting. The participants immerse in the game as avatars from a third-person's perspective (Figure 13). Their characters range from immigrants, elders, and parents to students and business professionals. At first, they are asked to seek a job, a place to live, or a place to socialize. During this process, they are allowed to chat with another player, asking to meet and trade their findings. Here, the respondents agree that playing a character was a powerful element of the game experience. The article argues that the immersive game facilitated the feeling of connection to the locals while they were participating. The study reports that most of the participants were at a mean age of 30, which lacks the input of a senior citizen in the

planning process. It is also unknown to what extent the participants play, whether with high attendance or energetic participation, as there is no analysis presented. And the development of the game tool is costly, which decreases the possibility of applying it in other urban contexts and situations. This is because of the nature of developing a game application, which always requires a story and a situation to accommodate relevant game rules. Besides, due to game rules, such platforms cannot provide intuitive design actions.

Figure 13 Participatory Chinatown exploration interface (Gordon & Schirra, 2011).

Poplin (2014) presents another serious game platform wherein they manage to engage elderly people. They also use the digital serious game application as a form of online-based civic engagement in urban planning. The gaming platform that they offer is 2D screen-based. The only immersive feature they have is the sound in the game. It does not allow participants to engage with the bodily experience in the environment. However, they have demonstrated a successful sharing of information between participants online.

Beattie et al. (2017) have also developed a framework for participatory city design through a fictional game with the belief that it can create a perceptual bridge for real-world problems. The article re-asserts that games not only can convey messages but can also simulate experiences that can be transformative, as the participants can be absorbed in the environment and, to some extent, they interpret the event as their personal experience (Bogost, 2007). The study faces the challenge of the diversity of stakeholders

of a marginal community in Shivaji Nagar, Mumbai. The researchers speculate that through interaction and discussion with the members in conflicting perspectives, they can seek common ground and accept other opinions and preferences positively; this relates to fostering greater cognitive consensus though 'Fictional Inquiry.' They employed 'Fictional Inquiry' as a design technique to develop the participatory artefacts in the gaming environment. It represents real-world objects and situations in an imaginary fictive world, where the new narration of artificial space reconfigured the cognitive consensus between the participants. The technique has the advantage of allowing participants to tackle real-world issues through an enjoyable process, and to create an environment that is well suited to imagining ideas for the future due to the low cost of failure. However, such fictional abstraction of real-world scenarios loses the connection of a real-world design task. Besides, similar to other gaming environments, as a rule-based system, it does not provide enough flexibility to intuitive design actions. Also, the proposed environment does not provide enough perceptual understanding of the investigated site due to the non-immersive character of the 2D display.

In a similar scheme, von Heland et al. (2015) used gaming interfaces as a tool to envisage possible urban scenarios in a project led by UN-Habitat (Figure 14). Here, they used the game Minecraft to collect consensus data from community participation in a rural neighbourhood in Nepal. The gaming interface allowed the participants to develop an urban design decision-making platform. The study responds to the identified need to establish innovative means to facilitate and encourage the active participation of youth in urban design decision-making. The article reports on the social impacts associated with the use of Minecraft, both on an individual and community level. It also informs that a common remark from participants was that visualisation played the crucial role in starting a discussion among people and that the gaming

interface was an important medium to facilitate not only conversations about space but also visioning about space.

Figure 14 A proposed redesign of the park in Nepal (von Heland et al., 2015)

One of the crucial arguments against these game-based platforms is that they make design decisions without understanding the 1:1 scale of the environment. Also, the visual representations that generate 3D artefacts are a combination of modular boxes, which reduces the quality of perceptual affordance to design intuitively and inter-relate the virtual contents to the real context.

5.1.3 Mixed-Medium of VR Collaboration

In 2014, the Department of Architecture of the Technical University of Munich developed design-supporting digital tools for architects that can provide combined information of calculations, analyses, and simulations (Petzold et al., 2014). They question the discrepancy of designers' design approach of switching media between physical models, analogue sketches, and digital tools. Their research proposes a bridging method to reduce the gap between the conventional working process and digitally supported tools (Figure 15). They speculate that designers can get real-time output for every single intervention in design decision. They expand their research to VR collaboration, though the idea is still in the conceptual stage. However, the setup requires enough empirical data to record its effectiveness.
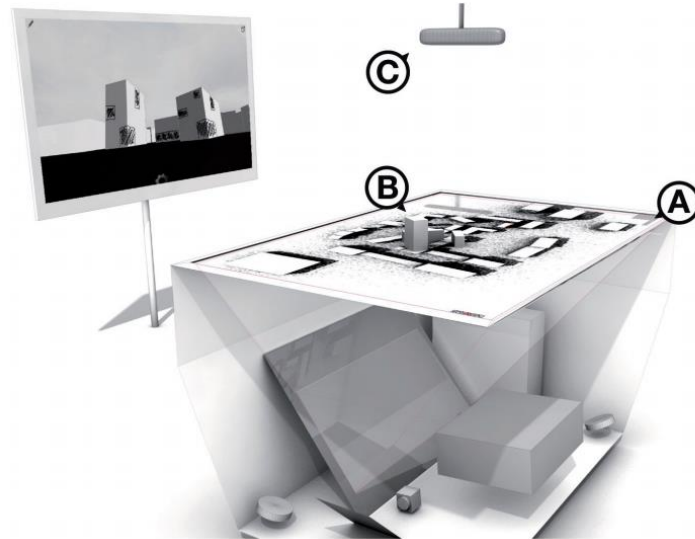
Figure 15 A setup for reconstructing physical models three-dimensionally in real time. All design information in real time is also available as digital data for the computation of design-supporting simulations.

(A) The table top serves as a work surface for designing using physical models (B) and hand sketches. Above an on-top mounted 3D depth camera (C) the physical models are digitized three-dimensionally in real time. So, all the design ideas are also directly available as digital data in the system (Petzold et al., 2014).

In the domain of transportation planning, Fischer and Ostwald (2005) examine stakeholders from transportation engineers to neighbourhood residents who work together to improve the design of bus routes in their neighbourhoods (Figure 16). In the 'action space' (space where the game is played), they use 'domain objects' such as buses, bus stops, neighbourhoods, and streets to explore different facets of the problem. An engineer may think of a bus stop in terms of its capacity to serve a certain size of the neighbourhood, whereas a resident may think of a bus stop in terms of its convenience to her/his house, or perhaps in terms of after-dark safety. They develop two different interfaces to collaborate with stakeholders. The bus stop object in the Envisionment and Discovery Collaboratory (EDC) is a boundary object for engineers and residents to build a shared understanding of the 'bus stop' concept in terms of the importance and implications of a particular design. This process is enhanced by the action space simulation, which helps stakeholders to explore alternatives, and the reflection space, which provides the background that informs each perspective. Now, due to advancement of the computational tools, the idea can embrace less traction data sharing between digital interfaces. Although the concept has positive

features to involve spontaneous stakeholders, the quality of the perceptual understanding is not in real scale. Besides, the used artefacts, which are referred to as boundary objects, coupled with technological interaction, are in a fixed format in regards to flexible design iteration. The research also does not provide enough evidence as to how the interfaces help the stakeholders to communicate a shared understanding in the decision-making process.

Figure 16 The Envisionment and Discovery Collaboratory (EDC) - in the action space (foreground), stakeholders use physical objects to interact with an underlying computational simulation environment. In the reflection space (background), stakeholders interact with an information space, in which they access information, fill out surveys, and add new information (Fischer & Ostwald, 2005).

5.2 Iterative Three-Dimensional Modelling as a Decision Support Tool

In this section, I discuss iterative three-dimensional modelling as decision support instruments in urban form ideations and generation. The focus of the discussion is on the concept of integrating such modelling techniques in urban planning and design. Thus, the discussion does not include all of the standalone software that is currently in use to develop such iterative 3D modelling platforms.

The design strategies for urban design and planning take a lot of information and knowledge into account regarding the various types of complex urban issues that require visualising in the design process. The lack of common language among such agents raises communication difficulties

(Beirão et al., 2011). The addition of parametric design develops an intelligent design system where that design becomes a computer model to aid in the understanding of how the different parts are related. Parametric Design along with a BIM modelling system has already pushed architects to aim for a new endeavour in building design. Such a design method offers distinct advantages for engineering and manufacturing processes (Schnabel, 2007). BIM comprises an integrated system that aims to incorporate all aspects of design, from geographical information and building geometry to the relationships between components and the quantities and detail properties of building components (Guarino, 1998; Montenegro & Duarte, 2009). The ontological description that corresponds to the city design process demands the creation of City Information Modelling (CIM). CIM allows a holistic approach to dealing with urban design on a large scale. However, commercial readily available instruments for CIM (Autodesk, McNeel, ESRI, etc.) are still not intuitive enough in switching scenarios to perform well in a design charrette (Antje Kunze et al., 2012). Besides, such design approaches still do not allow shared experiences between non-experts to make design decisions collaboratively.

5.2.1 City Information Modelling

City Information Modelling already extends its boundary by integrating Geographic Information Systems (ArcGIS) as a decision and design support tool (Figure 17). There is already established research that describes an urban design method that incorporates the stages of form generation and evaluation of urban models backed by CAD/GIS software platforms (Duarte et al., 2012). CIM enables a unique way to conduct top-down urban planning approaches. Researchers like Beirão (2012) try to integrate urban design principles into CIM models to deal with urban complexity. However, his exploration stands only for urban professionals who need to incorporate other design means to engage the end-users. This is due to the software interface, which requires expert knowledge to operate. This means technological affordance is not suitable for non-expert use. Besides, the proposed system

does not allow users to immerse in the VE and make intuitive design decisions.
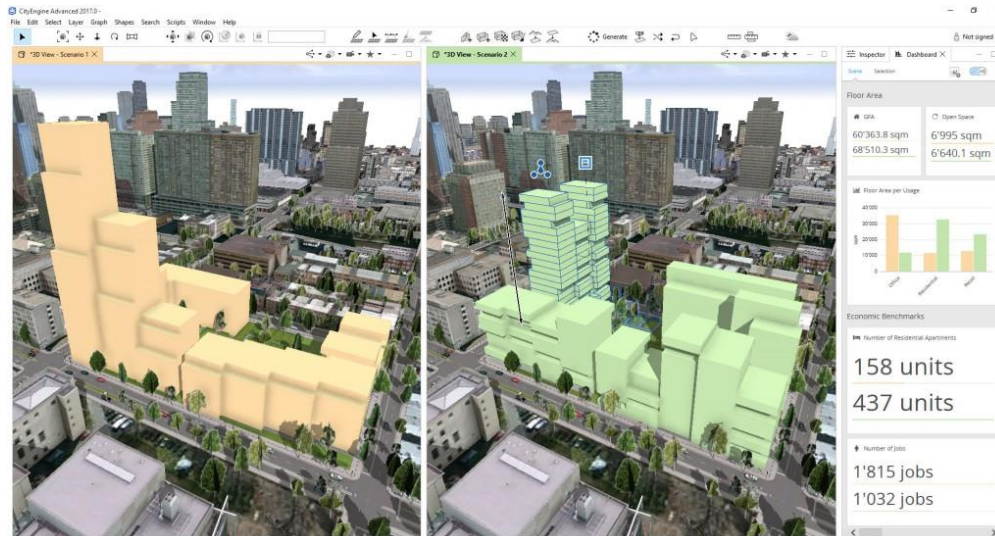
Figure 17 CityEngine city information modelling interface (ArcGIS, 2019).

5.2.2 Urban Strategy Playground

Urban Strategy Playground (Muchnik et al.), a research group at the Technical University of Munich, developed an interactive digital tool that could aid the political decision-making and planning process (Petzold et al., 2014; Seifert et al., 2016). They particularly focused on the densification of an inner-city neighbourhood. The tool supports the development of densification strategies that are well suited to specific urban contexts (Figure 18). The research argues that semantic 3D city models can offer an evaluative basis through the representation of spatial relationships and interactions by accessing analysis and simulation methods. They also argue that although information storage in urban planning is now becoming part of semantic 3D city models like integrated GIS or any other similar survey-based cadastral software, typically urban planning schemes cannot efficiently simulate building rules and their impact on the built environment. As a basic form of interaction, their developed tool provides a visual programming interface. The tool simulates building code and produces 3D city models. The researchers speculate that the tool enables the user to develop and customise desired functionality in real-time and thus implement user-defined analysis and calculation methods. The article presents the development process of this

tool as an object-oriented structure to produce iterative 3D building blocks. The manoeuvring parameters are designed to produce building volumes from plot area and height. However, the tool does not allow one to make design decisions on a spatial arrangement by becoming virtually immersed in the environment. The presented technology also failed to integrate flexible design participation. The interface is rich enough to present spatial-visual quality in a 3D space, but cannot offer interactive dynamic manipulations to engage emotionally while corresponding to alternative design ideation and generation. Besides, there is no evidence of how shared communication can occur in such a tool. The same as other gaming systems, here the system is operated by rules that have limited scope for intuitive design generations and ideations.
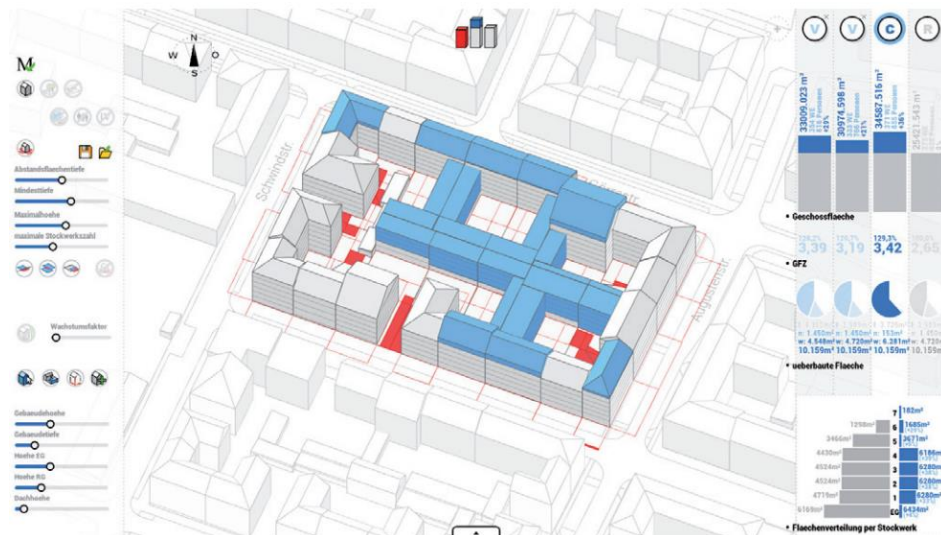
Figure 18 The visual programming interface (Seifert et al., 2016).

5.3 Virtual Reality in Design Collaboration

In this section, I discuss novel ways that are used and proposed in Virtual Reality (VR) design collaboration in urban design and planning. The focus of the discussion specifically is to seek VR instruments to support layperson's spontaneous proactive design participation.

VR modelling allows novel ways to merge real-life situations with virtual information in the field of Architecture, Engineering, and Construction (AEC) Industries. It has offered a variety of instruments to bridge the gap

between the idea of a design and its way of representation, communication, and realisation (Schnabel, 2009a). Virtual-Augmented-Mixed (VAM) Reality comprises a variety of realms from reality to virtuality, which has already been explored by design professionals as useful interaction instruments (Milgram & Colquhoun, 1999). Particularly, Augmented Reality (AR) allows interaction in a real-world environment by receiving computer-generated visual information. Collaborative AR has already been explored quite successfully in outdoor navigation by employing Latour's Object-Oriented Ontology (OOO), data management, data visualisation, and GIS tracking methods (Reitmayr & Schmalstieg, 2004). Also, researchers are trying to integrate simulation in virtual and augmented reality for architecture and urban design (Shimizu et al., 2017). Moreover, an application like "CityViewAR" has already added a new dimension to visualising historical buildings through mobile devices (Lee et al., 2012). Below, I discuss the literature on VR design collaboration and their types of representation in terms of generating intuitive 3D artefacts in IVE.

5.3.1 Virtual Reality Modelling Language

Virtual Reality Modelling Language (VRML) was the earliest version to provide access to integrating 3D urban models on the internet (Smith et al., 1998). VRML provided a flexible, cross-platform environment to model the urban form where the user can freely explore an urban model with details from any angle. It was suitable for any browser during that time. A user could move any aspect of the model on the x, y, and z axes. The ability to move aspects in the built environment independent of one another allowed own interpretation of any given design scenario. VRML faced difficulties achieving fluid movement with a higher level of realism due to the large polygons of the model. The research group also speculated that such movement within the models would facilitate consultation and allow the planning community to interact in a common digital space for a design solution. They presented several VR technologies, which were all destined to communicate planning and urban information to the end-user through the interaction of objects within the VE. They reported on the online avatar-based alpha world, blaxxum community client, sony community place, active

browsers, live chatting facilities, etc. They didn't test all of the interfaces in real cases. However, their collaborative venture Virtual Design Arena (VIDA) provided an insight into the use of virtual worlds for the visualisation of urban planning and urban design for educational and practical requirements (Figure 19). VIDA established a framework to explore and get feedback on urban model from the users, which was later explored by other researchers around the world (Figure 20). As an example, one of the developed interfaces by VIDA was alpha world, which allowed the users to include traditional CAD models into a VE. It provided a degree of flexibility in the design of the environment and the ability to construct a realistic-looking environment. However, due to the early version of the computational interface, it could not allow the users to take part actively in design ideation and generation stages, which explains the inability to generate intuitive 3D artefacts.
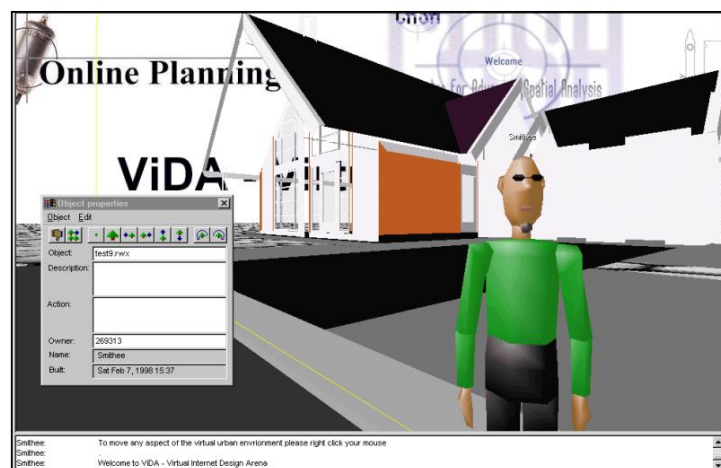
Figure 19 Alphaworld ViDA Interface (Smith et al., 1998).
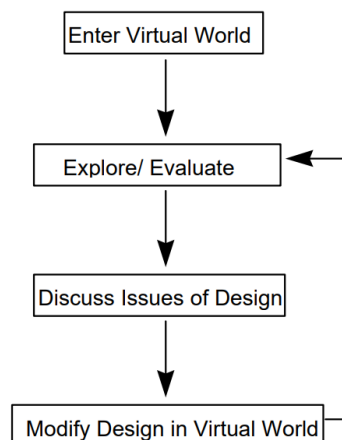
Figure 20 The basic virtual design process of ViDA (Smith et al., 1998).

5.3.2 Luminous Table

MIT School of Architecture, in collaboration with Media Lab, ran a successful holistic urban design approach in a graduate design course in 2002 (Ishii et al., 2002) (Figure 21). They argued that multi-layered manipulative platforms that integrate digital and physical representations would have a significant impact on the urban design and planning process. They had introduced 'Luminous Table,' an augmented reality to address the issues of integrating multiple urban forms into digital representations. They used the simultaneous method of physical and digital media for a holistic design approach. They explored a hybrid but seamless information space that would enrich the urban design process. They put physical models on two-dimensional maps and satellite photos on the table, and projected digital simulation onto the table surface. Later expanded versions akin to 'Luminous Table' are Petzold et al. (2014) tabletop physical model representation in 2D display and Seichter and Schnabel (2005) work on an AR urban design approach. However, all of the virtual content was not in a 1:1 scale. Also, the shared experiences were based on particular 3D artefacts, either physical or augmented, which could not generate a combination of cuboids during the process of design collaboration.
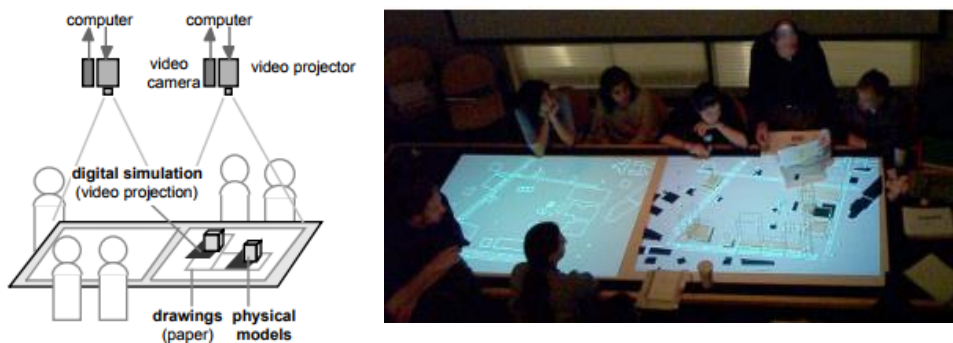
Figure 21 The Luminous Table supports multi-layering of 2D drawing, 3D physical models, and 2D video projection of digital simulation (Ishii et al., 2002).

5.3.3 Evaluation of a Virtual Environment for Architecture and Urban Planning

Drettakis et al. (2007) present a user-centred design approach to the development of a VE. It utilises an iterative, user-informed process in the

entire design development cycle. The study starts with a preliminary survey with the end-users, including urban professionals, to determine the elements necessary to make the VE useful in a real-world setting by adding appropriate graphical and auditory techniques. The site that was chosen was Place Garibaldi, Nice, where the urban community decided to build a tramway. Through the user-centred design approach, the research developed the appropriate interface and an evaluation methodology to test the usability of the system.

The evaluation results suggest that involving users from the beginning improves the effectiveness of the VE in the case of an urban planning project. It also shows that the appropriate levels of realism, in particular, spatialized 3D sound, high-detail vegetation, and shadows, as well as the presence of rendered people, plays a significant role in the design process; they enable better appreciation of the overall ambience of the VE, perception of space and objects, as well as sense of scale. The total number of participants was 25, and they engaged in three different design task situations. The authors admit that end-user feedback would have been completely unavailable if they had only limited the experiments to the graduate students.

The views have been fixed in the VR applications, which to some extent support the decision-making by placing the vegetation and umbrellas in the square (Figure 22). During the design session, the user can move around in the environment to evaluate the design results on the ground level, a fixed balcony view, and top view (Figure 23). That means the process of design decision-making happens in a fixed format, which does not allow one to make decisions by being a presence in the VE. The research reported two stages of observations: one is a laboratory experiment, and another is engaging people from City Hall. The evaluation is done through a survey with Likert scale marking and interviews. In laboratory testing, the participants were quite happy, as they were able to use the tool without difficulty, even without any prior experience with interactive 3D systems or video games. The authors admit that for brainstorming, this tool would be very useful. During the City Hall meeting, the participants also stated that the use of the system had brought significant clarification to their understanding of the project. They

mostly spent time on the choice of trees, the spacing of trees, and ground material. The engineers and politicians spent half of the time at the ground level and a half using the balcony view. They switched between different scenarios, which interrupted the continuity of the design collaboration. The VE can only deal with the placing of trees or roads around the square but is not capable enough to afford the design generation of urban form. Also, due to large distance manipulation from the object, the precision was insufficient, which means the application doesn't provide enough affordance of cognitive load to understand the environment in a 1:1 scale. Nevertheless, the realist features of sound, shadows, and an animated crowd brought a sense of real context during the design decision stage.

Figure 22 The top view of the VE is displayed with two sets of menus for the insertion and manipulation of dynamic objects. A small umbrella (circled in red) is attached with the wand (Drettakis et al., 2007).

Figure 23 Simulator snapshot of the balcony view of the Place Garibaldi, showing the Tramway passing though the square (Drettakis et al., 2007).

5.3.4 Digitalized Models for Design Collaboration

Seichter and Schnabel (2005) explore a collaborative urban design studio by using a tangible interface as a means for collaboration within Augmented Reality (AR) (Figure 24). Participants can actively participate in the design process and can load library models into their scene. Using an AR system, designers gain a more complex understanding of the relationships of their design and engage in richer communication with their partners. A positive aspect of the system is that the tangible paper-made models could interact with virtual 3D artefacts in a flexible manner. The instrument is able to locate virtual building form but not to generate multivariate intuitive 3D artefacts. Also, the interaction does not happen in a 1:1 scale, where the perceptual understanding would be different from the proposed one.

Figure 24 Images from Augmented Reality Urban Design Studio (Seichter, 2007).

Lo et al. (2019) present a multi-immersive VR technology for human-VR interaction through an efficient, transparent, and easy hands-on process in an urban scale 3D simulation. They present an AR-based table-top 3D simulation where the participants can interact with a simple hand gesture (Figure 25). The research can be placed after Seichter and Schnabel (2005) research on design interaction with tangible and digital contents. In contrast, Lo et al. (2019) have introduced a simulation in the design process. Simulation technique is good for representation, but not for the design generation and ideation stages. Besides, the current stage of the technological affordance cannot provide smooth features for users to perceive the context fully while designing. This means the VE cannot support design reflection on

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every design action with enough perceptual understanding. An empirical analysis is required to measure the effectiveness of the proposed system.

Figure 25 The Multi-immersive Remote Projector VR interaction (Lo et al., 2019).

5.3.5 Immersive Virtual Environment Design Collaboration

Schnabel (2011) shows successful architectural design studio experiments of virtual design communication within a team and remotely located teams. The research uses IVE in initial design stages for creation, development, form-finding, and collaboration of architectural design. They set up an experiment in a design studio that enabled students to design within a VE that embedded immersive tools into a broad context of Computer-Supported Collaborative Design (CSCD). The experiments happened between students in two remotely located institutes. The design collaboration between those two locations happened via online text chat (Figure 26). The research shows that the teams intensively discussed issues of design, concepts, and form. Due to the nature of the design task and the application, the teams have to discuss their design intentions remotely through chat. Between a team, the shared design experience is coupled with a natural flow of conversation. However, the text chat is missing the quality of colloquial conversation. It means every 'Mental Unit' member manages to show their higher quality of self-impression to others by highlighting their best aspects while concealing their negative thoughts. This means that natural conversation has more truth compared to digital ones. However, the result of the chatting protocol

suggests that participants could not only orient themselves easily within VE, but they were also able to extract the design intent of the remote team member without much difficulty. It shows that the virtual design tool and the environment blended harmoniously with the design process. The text chat records show the intense discussion about design, functions, and concepts. However, the exploration included expert students, where the procedure to generate building form depends on the scope of the instrument which has less perceptual affordance for first-time users.
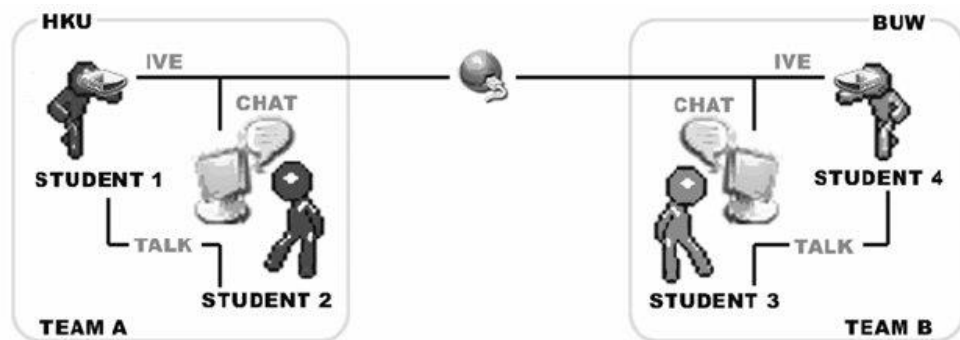
Figure 26 'Mental Unit': each side teams up in pairs to form one design unit (Schnabel, 2011).

5.3.6 Representation of Maquetteer's 3D Modelling Environment

de Klerk et al. (2019) have also presented a voxel-based immersive spatial design instrument. They have created custom-made interfaces to design in the VE. The research has compared two different immersive interfaces—one is 'Unity3D' based, and another is 'SketchUp' based—to report how fast the laypeople can do box modelling in a VE. Their developed Marquette (the 'Unity3D' based VR controller named by the researchers) can facilitate seamless interaction between the designers and the 3D models in full scale (Figure 27). Their interaction space is discretized into a regular 3D grid. The controller movement is fluid, and the cursor position is constrained to grid coordination, which limits the flexibility of locating the initial design starting point in the environment. The researchers have argued that using a regular grid helps the designers to place and orient 3D objects in space with mid-air gestures. They have given particular interest to the full-scale experience of the design. To achieve this, they adopt a real-time global illumination for day and night cycles to simulate sunlight with no ambient lighting. They have

engaged a total of 18 participants aged between 20 and 29 years who were asked to sketch virtually using both systems: 'Unity3D' and 'Sketch Up.' The engagement outcome reports that their custom-made VR tool builds long-standing design methods and goes back to the roots of the architectural design itself. The participants also reckoned that the system was a simple and effective design tool although the modelling canvas only constitutes a limited volume. Innes et al. (2017) also developed a similar kind of IVE tool, named as 'SketchPad' and tested with architecture students to see the potentiality of the tool as design ideation and generation tool. But the researchers didn't explore in the realm of shared collaborative design approaches.
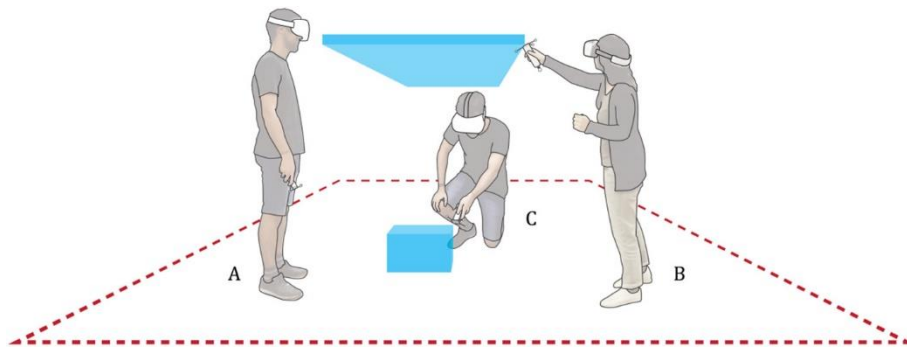
Figure 27 Representation of Maquetteer's 3D modelling environment, illustrating user's postures and gestures while building a model in VR: user standing, idle (A); user standing, modelling in VR (B); and user kneeling, modelling in VR (C) (de Klerk et al., 2019).

5.3.7 Virtual Reality in Urban Regeneration

Markopoulou et al. (2018) present a participatory process-fed urban regeneration project. They regenerate an area in Mumbai that included demolishment of the existing buildings and construction of high-rise residential towers based on the typology suggested by residents. The researchers design an open system through a virtual and augmented reality interface that would allow the residents to visualize different design scenarios and give feedback on the design scenarios they preferred. First, they did an extensive survey of the residents to collect data on the way the users inhabit space and the citizen's desires and needs. Their data ranges from working hours, leisure, and social activities, to mobility and settlement patterns. Based on the survey data, they developed a series of design solutions that incorporate community kitchens, leisure space, and social spaces like cinemas and lounges, with configuration depending on the working and living patterns

of the habitats. They developed modules using 'Grasshopper3D' to produce iterative design solutions and later used 'Unity3D' to visualize the space in a virtual reality atmosphere. To make the VR tools handy, they used Google Cardboard, which allows a smartphone to be transformed into a VR headset (Figure 28). They also offered an iterative AR interface running though tablet on a physical model to allow users to experience different design proposals in an immersive way and provide feedback on their preference. The intention was to integrate the users within an interface to make specific design decisions for private and public space, which then later could be assessed by stakeholders. In the end, the researchers admit that both interfaces had significant potential for the participation process, but had some important limitations such as the lack of communication between the designer and the user. Also, they are not capable enough to allow the designer to design with an enhanced immersive understanding of the investigating site.

Figure 28 Top AR visualizations of design proposals, below participation event in Mumbai: residents using VR devices (Markopoulou et al., 2018).

5.4   Summary

During a design process, iterations and reflections refine the design itself. In collaborative design settings, users have a variety of reflections and ways to communicate various design issues that need a clear visual representation. Table 2 illustrates the types of virtual instruments the researchers used and their capability to support intuitive design actions, design collaboration, IVE design decision-making, and testing in real-case.

Table 2 A summary of the research on different VE instruments in urban planning and design.

Research	Types of Instruments	Design Intuition	Design Collaboration	IVE Design Decision-making	Tested in Real-case
Lo et al. (2019)	Multi-immersive Remote Projector VR interaction	✗	✓	✓	✓
Markopoulou et al. (2018)	VR and AR interfaces to visualize different design scenarios to poor community people.	✗	✗	✓	✓
Cristie and Berger (2017)	Game engines to visualise scientific information on urban forms.	✗	✓	✓	✗
Beattie et al. (2017)	A desktop-based fictional game.	✗	✓	✗	✓
de Klerk et al. (2019)	A voxel-based immersive spatial design instrument.	✓	✓	✓	✗
Shimizu et al. (2017)	Integrating simulation in VR and AR.	✓	✓	✓	✓
Innes et al. (2017)	Interactive 1:1 Modelling as a Design Method	✓	✗	✓	✓
Seifert et al. (2016)	Parametric city design.	✗	✗	✓	✗
von Heland et al. (2015)	A desktop-based fictional Minecraft game.	✗	✓	✗	✓
Vemuri et al. (2014)	Serious gameplay approach in urban planning.	✗	✓	✓	✓
Petzold et al. (2014)	A mixed-medium table-top with	✓	✓	✓	✗

	physical models and real-time 3D visualisation.				
Poplin (2014)	Online based gameplay approach in urban planning for the elderly.	✗	✓	✗	✓
Antje Kunze et al. (2012)	CIM interfaces.	✗	✓	✓	✓
Lee et al. (2012)	CityViewAR	✗	✗	✓	✓
Gordon and Schirra (2011)	Immersive game in a community meeting planning.	✗	✓	✓	✓
Beirão et al. (2011)	Parametric design interface city design.	✗	✗	✗	✗
Schnabel (2011)	IVE design collaboration in studios.	✓	✓	✓	✓
Seichter and Schnabel (2005) & Seichter (2007)	An AR in urban design studio.	✓	✓	✓	✓
Drettakis et al. (2007)	VE for urban planning.	✗	✓	✓	✓
Fischer and Ostwald (2005)	Two interfaces. Interaction of physical objects with computational simulation and interaction with an information space.	✓	✓	✗	✓
Ishii et al. (2002)	Hybrid table-top based digital and physical representation.	✓	✓	✓	✗

| Smith et al. (1998) | Visual communication in urban planning. | × | ✓ | ✓ | × |

Above, the digital instruments in design participation are different from each other. Each instrument is designed to deal with a specific design problem. In some cases, researchers tried to adopt the existing software, whereas others developed the interface to interact with the participant. Due to the limitation of the instruments, different instruments have different types of abilities to engage users in design productions. It seems some of the instruments require expert knowledge to manoeuvre, whereas some are easy enough for users to use having limited knowledge of the instruments. Some instruments only can facilitate one user at a time, whereas some can facilitate design collaboration with other users.

Seifert et al. (2016), Antje Kunze et al. (2012) and Beirão et al. (2011) talk about parametric interfaces for design collaboration. Beattie et al. (2017), Cristie and Berger (2017), von Heland et al. (2015), Poplin (2014), Vemuri et al. (2014) and Schirra (2011) also present game-based participatory design instruments. As rule-based systems, their instruments cannot facilitate different design tasks except what the interfaces can offer. Besides, these also don't provide the opportunities to explore design ideation and generation in immersive 1:1 scale. Moreover, in some cases, the instruments require expert knowledge to deal with design. Petzold et al. (2014), Fischer and Ostwald (2005) and Ishii et al. (2002) talk about tabletop artefacts based design interactions, which requires expensive setup and can address limited parameter. Schnabel (2011), Gordon and Schirra (2011), de Klerk et al. (2019), Seichter and Schnabel (2005), Seichter (2007) and Smith et al. (1998) investigate immersive instruments and design collaboration. Every instrument is with different perceptual understanding and technological affordance with varying contents of design. Markopoulou et al. (2018) show a possible way to engage a poor community in VR, but the instrument only can represent a scenario which can not allow the users to design by themselves. Only de Klerk et al. (2019) and Innes et al. (2017) present

immersive VR instruments to design intuitively in 1:1 scale, but speculated for architectural designers without any collaborative participatory framework. Schnabel (2011) also presents a framework for design collaboration in near and distant manners but only explored within architectural students. To operate such instruments the designers also need to acquire expert knowledge. It seems that most of the researches are still in conceptual stages and have only been tested in the laboratory. However, one thing is evident: all are developing instruments to facilitate the design decision-making process and make it easier and comprehensive. The constant evolution of technology has changed the course of adopting a single virtual instrument; rather, it would be beneficial to develop a framework for a new instrument to deal with specific tasks.

For my research, initially, I developed rule-based instruments in 'Grasshopper3D' with an immersive extension to 'Unity3D'. Later I adapted Innes et al. (2017) 'SketchPad' to develop the VE experiment setup for non-experts to participate in urban design ideation and generation stage, which is described in Chapter 7.

Chapter 6 Research Methodology

Within a framework of qualitative research, a series of surveys and experiments were set up to investigate the scope of laypeople's active design ideation, generation, and collaboration in neighbourhood design. The methodology incorporates a preliminary survey of urban design consultation, development of the VR instrument, laypeople VE design experiment, a feedback survey on the experiment, an audio recording of the design conversation, transcribing recorded data, protocol analysis, and expert evaluation (Figure 29).
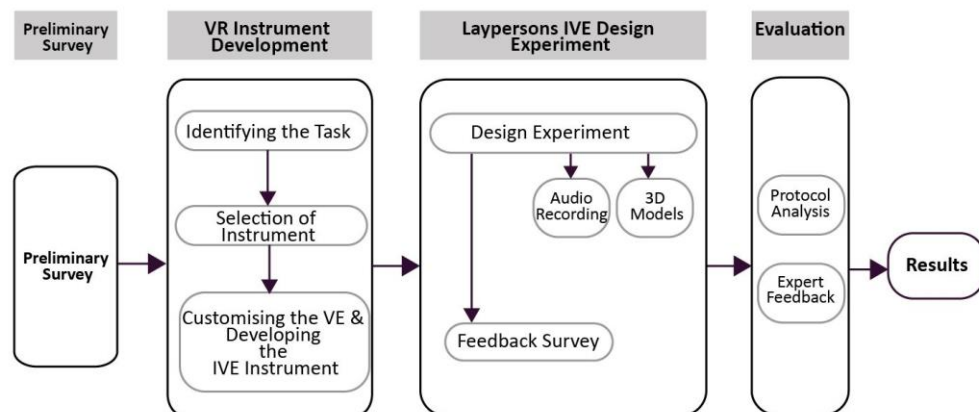
Figure 29 *Research Methodology.*

6.1 Preliminary Survey

A questionnaire was conducted to understand the design communication and collaboration of an urban design consultation. The survey helps to understand how laypeople compare different design ideas presented in the design process and how they take part in the design process. The preliminary survey has done exactly after the WCC consultation, which helped me to refine the primary study not to compare with feedback survey. Chapter 7.1 states the survey questions.

6.2 VR Instrument Development

An immersive collaborative design instrument was developed to incorporate intuitive design decision. This procedure follows identifying the task, then selection of an instrument, and finally customising the instrument.

6.2.1 Identifying the Task

The design task develops according to the interests and needs of the Karori residents following the results of the preliminary survey. Chapter 7.3.1 describes the design task.

6.2.2 Selection of Instrument

Involving non-experts and their responses to the design task require an intuitive immersive instrument with a low threshold interface and minimum training requirement. The quality of the perceptual affordance of the instrument supports the flow of generating design ideas through collaboration. Sanders (2002) mentions that "Make Tools" are becoming a new language for co-design, which serve as a common ground for connecting the thoughts and ideas of people from different disciplines and perspectives. Immersive instruments like 'Fuzor,' 'Grasshopper3D,' 'VR sketch,' 'Unity3D,' and 'Hyve3D' have features that require expert knowledge to operate. However, a customised one responding to the design task can easily involve laypeople with data exchange between immersive VE to 2D display. Chapter 7.2 describes the details of the instruments.

6.2.3 Customising the VE and Developing the Instrument

After selecting the instrument, the customising of the VE coupled with 3D modelling is undertaken to enhance the perceptual understanding of the case site. For example, some additional features of simulation add more aspects to perception. The unit set up of experiment between IVE and 2D display makes the design collaboration meaningful by allowing continuity in conversation. Chapter 7.2.2 describes the details of the instrument development.

6.3 Laypeople VE Design Experiment

Residents from the local community were recruited for the VE design experiment. The recruitment procedure happened by invitation through social media, circulating posters, and personal soliciting in public spaces. An introduction to the design task and training start at the beginning of every session. The design experiment is stated in Chapter 7.2.3.

6.3.1 Design Experiment

The design experiment starts after an introduction to the VR instrument. The experiment follows by giving the task to the designers and requesting them to explicitly convey their opinions through verbal conversations. One designer talks at a time and seeks clarification from another designer.

6.3.1.1   Audio Recording

During the VE design experiment, the design discussion is audio recorded to allow for focused group protocol analysis. The transcript is coded by two persons. In the thesis, the detail of the coding scheme is mentioned in Chapter 8.3.1 and the transcribed conversations are annexed in Appendix B.

6.3.1.2   3D Models

The generated 3D models are saved for expert evaluations and to record the type of proposed functions on the case site. Chapter 8.1.3 illustrates the generated models.

6.3.1.3 *Feedback Survey*

A questionnaire after the VE design experiment asks about the understanding of the spatial arrangement and design collaboration. The details of the questions are stated in Chapter 7.3.3 and the results with analysis appear in Chapter 8.1.2. The "Feedback Survey" counts the responses from 17 participants of eight sessions of the VE experiment. According to Guest et al. (2017) three focus group sessions are enough to identify all of the most prevalent themes. Creswell and Poth (2016, pp. 77-83), as well as Sim et al. (2018) suggest that for a qualitative research 3-10 participants is sufficient for meaningful analysis.

6.4 Evaluation

A focused group protocol analysis was done to analyse design communication between laypeople. Also, experts assessed the design communication by evaluating the meaning of design proposals.

6.4.1 Protocol Analysis

The details of the protocol analysis of VR design participation is described in Chapter 8.3. The advantages of protocol analysis discussed earlier in section 4.4. Derived from Tsai et al. (2009) and inspired by Ericsson and Simon (1993), a coding scheme was developed to analyse design communication and collaboration based on three sessions, which are recorded during the IVE experiment. The coding scheme is described elaborately in Chapter 8.3.1.

6.4.2 Expert Feedback

Architectural experts were invited to rank the generated design. Experts evaluated the generated urban form by experiencing the design in the VE in terms of functionality, aesthetic, and experientially. Chapter 8.2 states expert evaluation.

6.5 Results

The results categorize the protocol analysis, expert evaluation, and two surveys to respond to the research question. Chapter 8.1 states the results of

the preliminary survey, feedback survey, generated designs, and expert's evaluation.

Chapter 7 Surveys and Methods, Instrument Development, Design Experiment, and Design Task

This chapter discusses the survey on design consultation, the instrument development and design experiment, the design task, and the survey after the IVE design experiment.

7.1 Preliminary Survey

This section reports a survey, which was done on design communication and collaboration of an urban design consultation organised by WCC in the community. In Karori, WCC ran year-long charrettes to understand the community interests and priorities and identify locations for further development (Karori, 2017; Wellington.govt.nz, 2017). Based on that information, they develop several design options. They also considered feedback from representatives from the community as a focus group to develop those ideas, and later they arranged a consultation event to collect votes and find the preferred design option from the majority of the Karori people. The survey helps to understand how laypeople compare different

design ideas presented in the design process and how they take part in the design process.

7.1.1 Existing Consultation Process

WCC ran a design consultation with the Karori community on 7th November 2018, where they presented four Karori Neighbourhood design options. The event followed the suggested method of community meeting as "Hui" in *Urban Design Toolkit (Mfe.govt.nz, 2009)*. This method is useful for distributing information and undertaking consultation, but it offers limited opportunity to involve people in one-to-one dialogue and participation. The purpose of the community meeting is to present and explain design proposals to a group of residents, stakeholders, or "iwi" and "hapu," and provide an opportunity to ask questions and receive an immediate answer.

During that event, WCC proposed four different design ideas for re-designing the Karori neighbourhood. The design ideas had been presented in a 2D colour printed medium with a perspective and a plan for every design option (Figure 30). The session started with a presentation, then a question and answer session with the Karori people, and finally a voting session on the design options. I handed out a questionnaire after the intro session. The total number of respondents was 30. The participants were mixed gender and ages between 30-60 years. They voluntarily participated and the selection process was random. The aim of the survey was to identify how presented media supports the Karori people as they take part in the design ideation and collaboration process. The results of the survey are reported in Chapter 8.1.1.

Section 2 – Tell us what you think of the options

Option A – A shared space with improved pedestrian connection

Features and improvements you can expect to see:

- A flexible public space that still supports parking but is also designed for community events and activities.
- A new pedestrian connection is created for people to walk between Campbell Street and Beauchamp Street via the St John's site.
- A quality new public space that supports the Community Centre, the Karori Arts and Crafts Centre, the Recreation Centre and the Events Centre.
- Pedestrians and vehicles share the space, encouraging drivers to move slowly and safely.
- Removal of eight car parks.
- New paving, plants and street lighting.

Artist impression: Option A – View looking at the Community Centre and Event Centre

Option B – Library Square and England Lane Improvement

This option upgrades the existing Library Square into an attractive, comfortable and sheltered space that welcomes the public into the library and the café.

For this option we will reduce the slope of the ramp between the Library Square, the Community Centre, the Karori Arts and Craft Centre and the Recreation Centre.

Features and improvements you can expect to see:

- A more comfortable, attractive and sheltered library square.
- Improved pedestrian connection through to facilities such as the Community Centre, Karori Arts and Crafts Centre and the Events Centre due to reducing the steepness of the ramp.
- Improved entranceway to the Recreation Centre.
- New paving, planting and street furniture.
- Retaining the public toilets.
- Improved outdoor seating area for the café to better define their space.

Artist impression: Option B – View from Karori Road into the new Library Square

Option C – Parkvale Road Pedestrian Priority Area

This option creates a pedestrian priority area for Parkvale Road. Pedestrian priority areas encourage drivers to share the space safely with pedestrians by slowing down and driving with care. Pedestrians have more freedom to move safely around this kind of street. Businesses are encouraged to open out onto the footpath because of better quality public space and the presence of more pedestrians.

Features and improvements you can expect to see:

- Wider footpaths allowing more space for pedestrians.
- New paving, planting, street furniture, and lighting.
- Outdoor seating areas that encourage businesses to bring their activities out onto the street, creating vibrancy and life on the street.
- Removal of four car parks.
- Switching from angle parking to parallel parking along the mall, which is a safer option in a pedestrian priority area.

Artist impression: Option C – View up Parkvale Road to Karori Road

Figure 30 WCC consultation design options (Wellington.govt.nz, 2019a).

WCC has announced the most popular option out of the four designs that went out for public consultation as per the vote. Option B is the most popular one (Wellington.govt.nz, 2019a) (Figure 31). The January 30th 2019 *Independent Herald News* mentioned that the option was chosen after receiving 300 online submission and onsite Charrette engagement process. Around 40 % the respondents said they preferred Option B, 26 % Option A, 23% Option C, and 11% Option D.

Option B aims to improve public space around Library Square and England Lane (Wellington.govt.nz, 2019a). WCC proposes that the Library Square upgrade will facilitate attractive, comfortable, and sheltered spaces to support public activities in the library and the café. They state that inhabitants will enjoy better access to the Community Centre, the Arts and Craft Centre, the Recreation Centre, and the future Events Centre.

Figure 31 Option B to improve public space around Library Square and England Lane (Wellington.govt.nz, 2019a)

7.1.2 Survey Questions

The survey questions are arranged to document if the visual information the participants receive in the consultation process is enough for them to visualise the proposed design ideas. It is required to have enough visual information to speculate on urban spatial arrangement. As I have discussed in Chapter 3.1, in a participatory decision-making process, it is required to have spontaneous stakeholder feedback to find a design solution that meets most of the local people's interests. The questions have been categorized in such a way that the same questions can be asked during the VE design experiment. The survey intends to report how the laypeople communicated and participated in the consultation process. The questions ask about the quality of the given

information to aid in understanding the spatial arrangement, the level of design visualization of the proposed design ideas, the level of design perception in 1:1 scale, the level of collaboration during the process, and individual interest to design by themselves or if they prefer set design—or a mix of both.

7.2   *Instrument Development and Experiment*

The development of a VR instrument is one of the major parts of this thesis. It seeks to facilitate laypeople's collaborative design ideation and generation in the Karori neighbourhood design process. The challenges of developing such instruments include the understanding of the algorithm of the systems, and the need to sort out a suitable one that can facilitate the design task and laypeople's design participation within the research timeframe along with available technical knowledge and resources. Below, it is described as the procedure of developing the instrument to produce intuitive 3D models. The instrument is developed to produce urban form flexibly with design collaboration by immersing a participant in the virtual environment.

7.2.1 Earlier Instruments

As a part of this thesis, I developed an instrument to generate the urban form based on parameters related to building height, plot ratio, land division, construction cost, and building width. It is scripted in 'Grasshopper3D.' It follows Schnabel (2007) concept, where architects do not prescribe a fixed gestalt, but rely on a set of rules and instructions that can inform and generate the desired outcome. The instrument allows a reaction on a variety of site-specific variables that can be modified according to the need. It offers an interface to visualise numerous alternatives of urban form by playing with the parameters. The interface also can be accessed through the internet and create an extended link to 'Unity3D' for an immersive experience.

One of the limitations of this instrument is that it generates urban form only by a fixed number. It does not offer enough flexibility for the designer to design apart from the offered parameters in the interface. It cannot rapidly capture initial concepts or ideas due to the lack of immediacy and

expressiveness. This limitation is mostly because of the inherent complexity of the desktop-based interface and non-flexible iteration of 3D artefacts. I have published two articles on the concept of developing these instruments.

I also develop a 'Fuzor'-based immersive environment for Karori. 'Fuzor' has the advantage of placing different urban design elements in the immersive world and can collaborate remotely in the avatar modes. I upload multiple landscape elements suitable for the Karori neighbourhood. The instrument can be seen as an immersive extension of Drettakis et al. (2007) tool, where the users designed vegetation and other landscape elements in fixed views on a 2D display screen. However, due to the different design task, I seek another instrument that can generate urban form in a flexible manner with natural affordance.

7.2.2 Employed Instrument

Continuum viewing of surroundings, conformance to human vision, and freedom of movement in the VE increase the quality of the experience of visual immersiveness (WhatIs.com, 2016). So, due to its flexibility to create iterative 3D models through hand gesture, an immersive instrument has been developed using the in-game-engine software 'Unity3D.' The initial modelling technique is described as 'SketchPad' by Innes et al. (2017), and is akin to de Klerk et al. (2019) custom-made VR tool. I have adapted parts of it and extended it to the surrounding urban context. In the design experiment setup, one person at a time is immersed in the VE, whilst the other person visualises real-time design output on a 2D display screen and provides verbal feedback to the first participant. The conversation in the design sessions is audio recorded. The method is akin to Schnabel's (2011) IVE design studio research.

The relevant structures of the Karori Centre are modelled in fine detail to resemble the buildings and the contextual urban elements in the virtual environment. To achieve the expected accuracy of the 3D building models with surrounding information, the geographical information system (GIS) generated a topography that is imported to develop the 3D mesh of the terrain and to position the models on the terrain. Due to model making constraints in

'Unity3D,' the contextual topographical terrain 3D model is imported as Obj. format developed in 'Rhino3D.' 'Rhino3D' has compatibility to produce GIS accurate data integrated with topographical 3D mesh. The model material assignment is done in the 'Unity3D' game engine. The abstract 3D models of the Karori Centre are able to provide perceptual understanding to the designers to recognise the context.

The IVE interface is scripted in 'Unity3D,' where the participant can select different geometrical shapes to build their objects. The surrounding 3D model information provides continuous feedback to inform subsequent design moves. The participant is able to jump from place to place, look around in the environment, and make a decision on building forms by experimenting with geometrical attributes offered by the interface. The interface facilitates the creation of any shape of cuboids, and the size is dependent on the extent of the participant's reach.

7.2.3 Immersive Experiment

An immersive experiment setup has developed to leverage non-experts designers to participate together in an urban design discussion with the help of the representation of 3D artefacts. *Designer A* sees the VE immersed through a Head-Mounted Display (HMD) and as a first-person point of view, he interacts with the 3D artefacts via a controlling device to generate, delete and alter the design. *Designer B* sees the 3D artefacts through an 80-inch display screen and as a third-person point of view, he interacts with the artefacts through instructing *Designer A* to execute his design vision. The experiment setup brings the generated ideas of *Designer A* to *Designer B*. Figure 32 shows a diagram of a design unit. The diagram is triadic as they are closely related entities and depending on each other actions. They follow a conversation protocol during their design sessions. *Designer A* generates design action and seeks verbal feedback from *Designer B.* The IVE instrument and design task can establish a communication between *Designer A* and *Designer B.* The process follows a sequence of actions from *Designer A* to *Designer B* through the representation of 3D artefacts in the display screen.
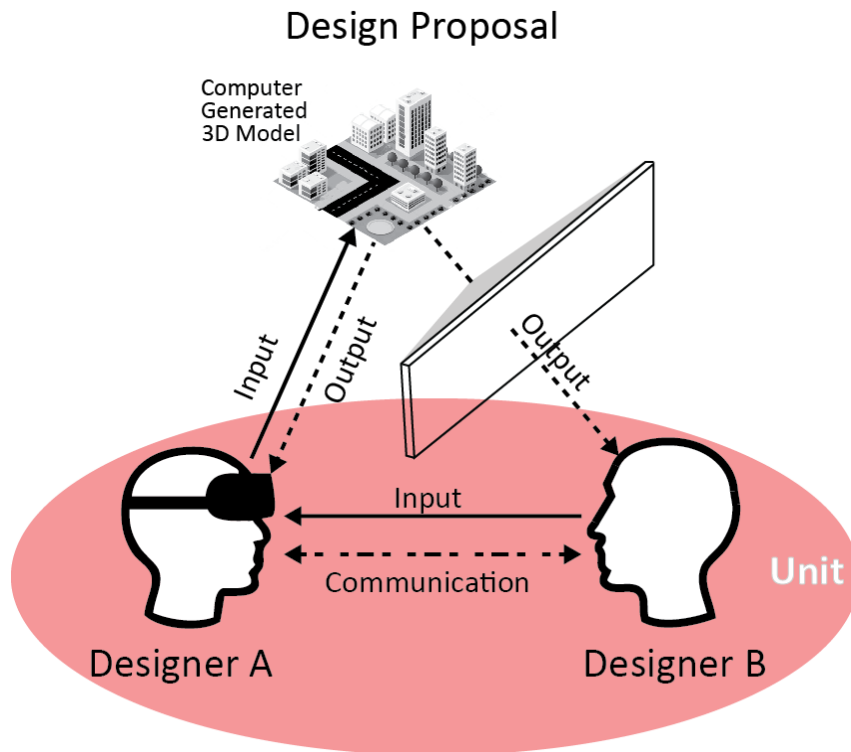
Figure 32 One unit of 'Enhanced Communication''.

The 3D artefacts are communicated through the HMD, and the display screen, where *Designer A* is immersed in VE and *Designer B* is partially immersed through the large screen, a screen-based immersed. As the 3D artefacts are generating in a virtual urban environment, so they together represent an urban form in the environment. The perceptual quality of VE facilitates such an abstract understanding of the urban form. *Designer A* generates 3D artefacts as a representation of urban form as input in VE and the output from VE goes to *Designer B*. *Designer B* can be a group of persons. The experiment setup can bring a feeling of affiliation with each other activities during the design sessions. The communication process may let the designers design together as a team rather than acting as individual actors. The collected data from the design experiments can reflect on design collaboration.

A design task is introduced supporting the contextual need. In this case, for the Karori suburb, the participants are asked to design building blocks on the corner empty plot in the Centre. The session begins with the introduction of the VR instruments to the participants and orients them with the Karori Centre site on a Google map. The participants are allowed to

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extend their design ideas beyond the assigned plot if they wish to intervene. I set an event in the Karori Community Centre in situ a part of the site to engage local people in the instrument. I stationed there for two days and recruited a total of seven volunteers in three different sessions. The sessions ended with a questionnaire survey and an audio recording. The audio recording was analysed through the protocol analysis method by developing codes for categorizing the verbal communication and transcribing the conversation. The method was chosen to evaluate the interactive quality of the collected data. The generated 3D models were saved for experts' evaluation.

7.3   Design Task and Feedback Survey

This section informs about design tasks that have been given to the participants during their virtual engagement. It also informs about the survey that has done after the virtual design engagement.

7.3.1 Design Task

According to the WCC's proposition, the future redevelopment considers the urban blocks around the Karori Library (Figure 33). The corner plot between Campbell Street and Karori Road, the St John's Church Site, has been considered for redevelopment (Wellington.govt.nz, 2019b). WCC also
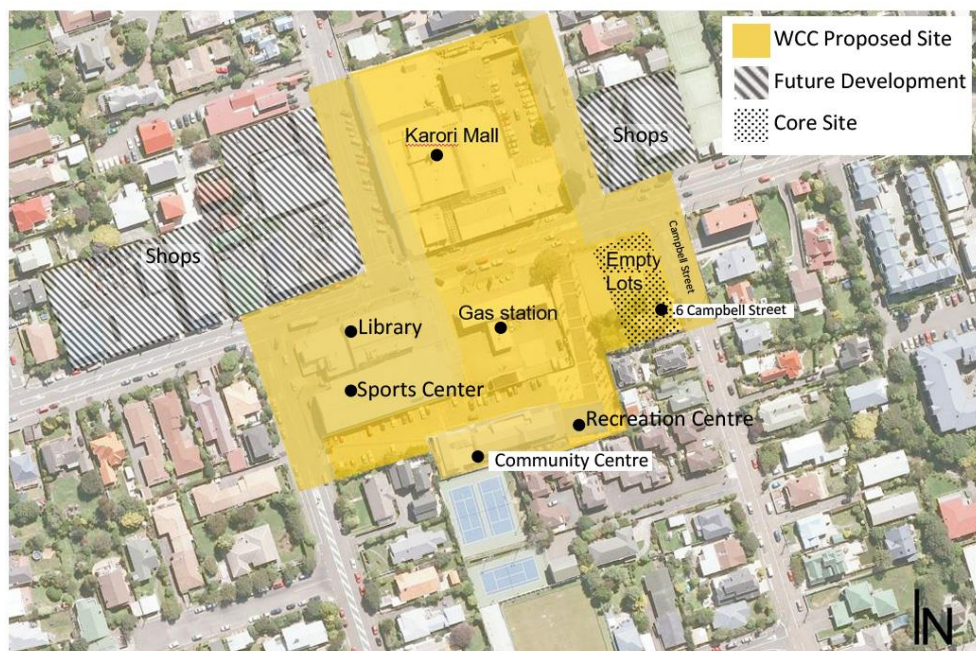
Figure 33* Karori Centre Google map site (not in scale).

considers the 6 Campbell Street lot for future development. The proposed plan is to transform Karori into a single Business Improvement District (BID) in future.

Addressing the future development plan of WCC and the interest of the local community, I have set the design tasks for design participation in the virtual instruments. The design task is to generate ideas of urban form as well as spatial arrangements. According to the scope of the virtual instruments, the task is modified a bit to investigate the design communication between participant-participant and participant-computer.

7.3.2 Design Experiment, Procedure, and Tools

The design experiment was held in the Karori Community Centre on 26th and 27th January 2019. The event had set three-time slots for three different sessions on each day. We had circulated the recruitment ad through social media and posters around the Karori Centre, and talked to people to recruit the participants.

The experiment procedure distributes the design task to the participants. One person designs in an immersive environment and others provide feedback. This is done due to the nature of the VR instruments. More than two people participated in the engagement. The session starts with the introduction of the project and a description of the design task. A Google map of the Karori neighbourhood has been used to orient the participants with the context. Then, the VR instrument is introduced to them and everybody goes through a short session while wearing the VR headset for 10 minutes. This is done to overcome the unfamiliarity and challenges of the new environment and the instrument. Next, one of the participants is asked to be the HMD designer and others to become the design participants. The participants continue to design conversation monitoring on an 80-inch display screen (Figure 34). This means that whatever the designer is designing in the immersive virtual environment can be seen simultaneously by other participants. The whole VR design session is audio recorded. To add clarity to the discussion flow, the participants are requested to speak one person at a time. The whole process lets the participants negotiate between themselves to

come up with an urban form in the empty corner plot of Karori. They start their design session on the negotiation of the types and functions of the building form. Finally, we survey to report how such a virtual design decision-making platform can help the participants to visualise their proposed design ideas in their neighbourhood.

Experiment steps:

1. Orient the participant with the controller of the virtual tool.

2. The HMD designer (while seated/standing) and other participants design through conversation.

3. Post-Experiment survey.

Total time: 50 min.

Experiment tools:

1. HTC Vive headsets to let the designers design in IVE.
2. Desktop PC with software: 'Unity 3D' and 'Steam VR.'
3. An 80 inch screen to display with 1920 X 1080 resolution.

Figure 34 VE design engagement in the Karori Community Centre.*

4. A printed Google map of Karori to orient participants in the design discussion.

5. Questionnaire

7.3.3 Feedback Survey Questions

The survey was conducted after the virtual design experience. There were altogether 17 people participated in eight different sessions. They participated voluntarily. Most of them were aged between 31-55 years and mixed gender. The questions align with the previous survey questions asked during the design consultation arranged by WCC. The questions ask about the visual information needed to understand the spatial arrangement in the VR environment, the effectiveness of the abstraction of produced models to initiate design ideas, whether the contextual site information guiding them to take design decision, is the visual information enough to make fully informed decision, what should be changed/improved/added, the ease of design collaboration with stakeholders, and their preference to take part in the design. It also asks about participants' 3D skills. 3D skilled means whether the participants have extensive knowledge of working with 3D modelling software. A copy of the questionnaire is attached in Appendix B.

Chapter 8 Results and Analysis

The results of the consultation survey, the virtual design survey, and the protocol analysis are reported in this chapter. To validate the virtual design outcome, I evaluate them with an expert panel. In addition to identifying the effect of design communication, a protocol analysis of the conversion is done, which was recorded during the virtual design engagement.

8.1 Results

Two questionnaire surveys report on the level of stakeholder collaboration and the quality of design communication. The questions are asked to determine whether the participants want to take part as designers in the urban design process.

8.1.1 Results on Preliminary Survey

The survey outcome of the WCC held consultation process comes to the conclusion that the participants want to take part as active designers in the design process. There were 30 participants (n = 30). The measuring value of each answer is the level of choices like 'Absolutely,' 'It is Ok,' 'Neutral,' 'Not Really,' and 'Not at All.' Respondents chose 'Absolutely' when they were 100% satisfied, chose 'It is Ok' when they were just more than 50% satisfied, chose 'Neutral' when their response was 50-50, chose ' Not Really' when they agreed on a little bit of the question, and finally, ' Not at All' means that the participants completely disagreed with the question.

The question on design collaboration received mixed opinions as the communication process happened with minimum visual information via 2D rendered images and textual description (Figure 35). Almost 31% of the participants agree that during the consultation process the collaboration happened very easily. 24.1% of people are in a moderately satisfied or neutral position. However, 10.3% of respondents show negative acceptance of the collaboration process. On the other hand, none of them said that there is no collaboration.
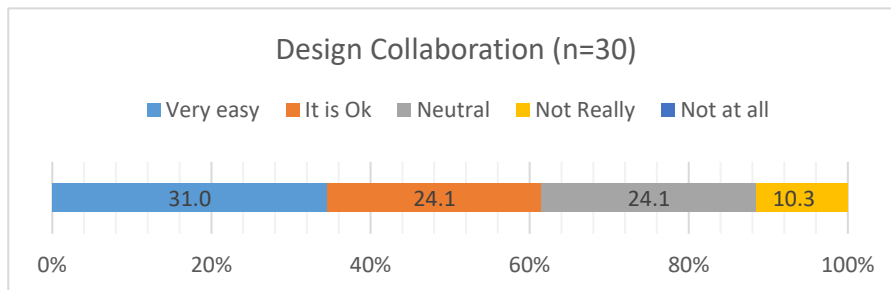
Figure 35 Design collaboration in WCC consultation process.*

In terms of understanding the spatial arrangement, the participants agree that they understand the proposed spatial design options. 44.8% of participants strongly agree that the WCC proposed plan, perspectives, and presented information is good enough to speculate about the new urban spatial arrangement (Figure 36). Again, almost the same percentage of people show moderately accepted opinions. However, in contrast, 3.4% of participants claim that they can hardly understand the proposed spatial configuration. Similarly, in the case of perceiving urban space in human scale,

53.6% participants strongly agree on visualising design alternatives in 1:1 scale, whereas 35.7% of them moderately agree on visualising design options in human scale.
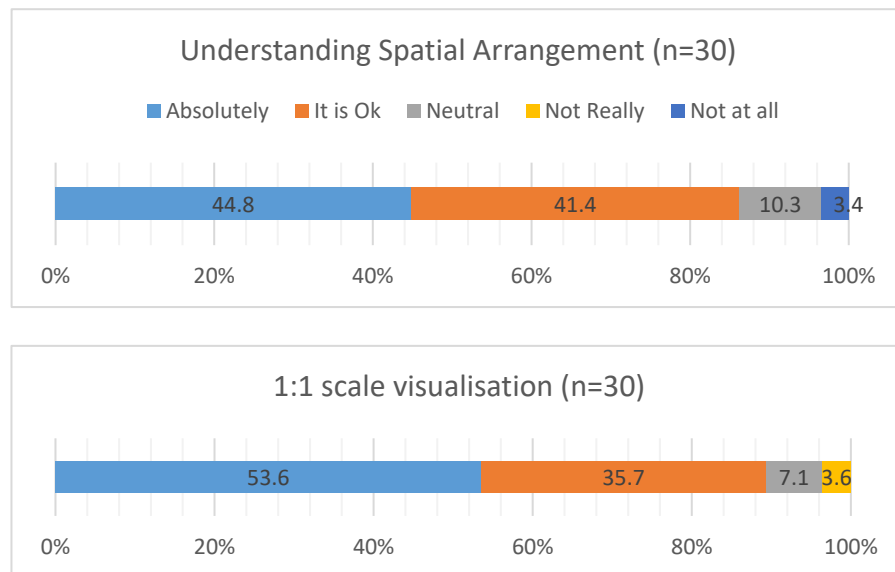
Figure 36 Understanding spatial arrangement and 1:1 scale visualisation.*

In terms of creating their own design, 53.8% of participants want to create their own design along with a proposed set design solution (Figure 37). There are 34.6% of people who also want to have a set design solution. There is also a handful of people who want to completely design by themselves.
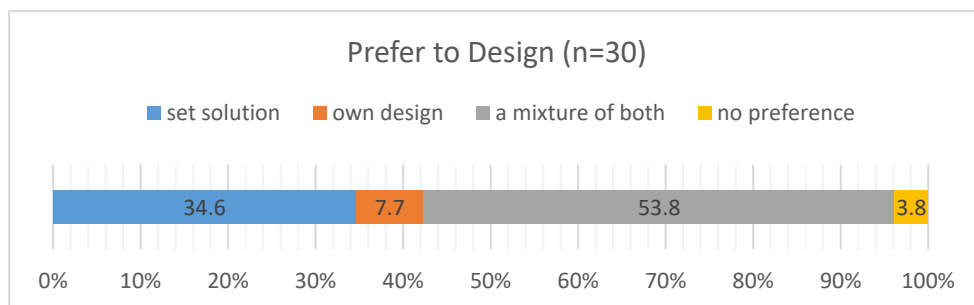
Figure 37 Prefer to design.*

There was one question about what to be changed/improved/added to the understanding of the design options. Some of them answered it. Some answers are: "Identification and acknowledgement of other projects", "3D walkthrough online", "3D models", "a movie or digital walk through", "more detailed maps of the neighbourhood", "not enough information, afraid some of the proposed options which would have negative impacts", "consultation all the day", "There needs to be a common connection between the designs

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so that they be evaluated", "other info, i.e. wind/sun/etc.", "the current state is good-not at detailed design yet", "the options need to reflect the consultation, they don't", "better communication about the process to achieve more engagement", "N/A", and "easier explanation".

In summary, the survey of the consultation process shows that participants from the Karori community prefer to design by themselves, though they have mixed opinions on understanding the proposed urban spatial arrangement of their neighbourhood centre.

8.1.2 Results on Feedback Survey

In the research, 42.9% of the participants had no previous experience in 3D modelling (Figure 38).

3D Skilled (n=17)

■ Yes ■ No

57.1	42.9
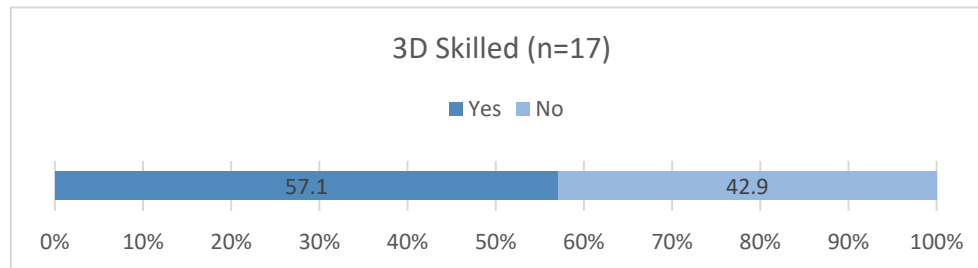
Figure 38 3D design skilled.*

The answers of question 3 indicate that the contextual site information guiding the participants to take their design decision. More than 60% of participants agree that the contextual perceptual understanding supported them to perceive Karori in the VE (Figure 39). No participants said that they did not understand the contextual model of Karori in the virtual environment.

Contextual Understanding (n=17)

■ Very much ■ It is Ok ■ Neutral

63.6	9.1	27.3
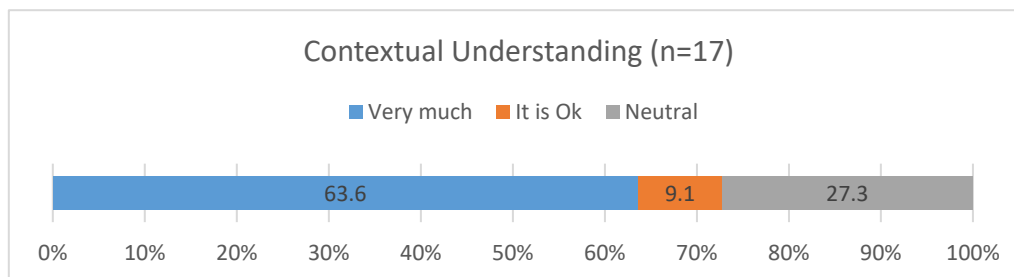
Figure 39 Contextual understanding in VE experiment.*

In the case of understanding spatial arrangement, nobody shows disagreement on the understanding of spatial arrangement in the VE engagement (Figure 40). However, as Figure 36 shows, 3.4% (n=30) of

participants agree they cannot understand the spatial arrangement during the consultation process.
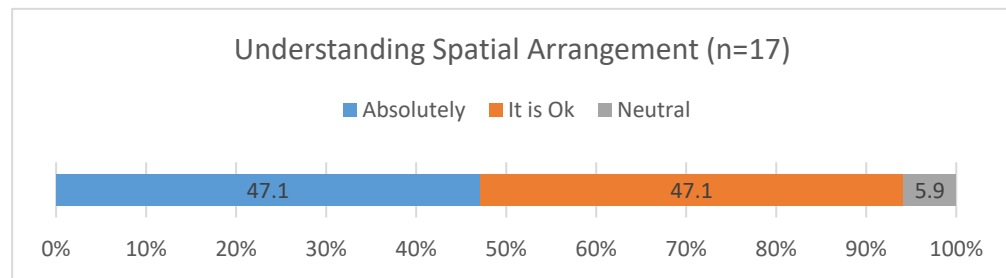
Figure 41 *Understanding spatial arrangement in VE experiment.*

Figure 41 sums up the answers of the question 4. Every participant agrees that the visual information enough to make fully informed decision. The figure shows that 16.7% participants completely convinced by the visual information and 83.3% participants showed acceptable responses.
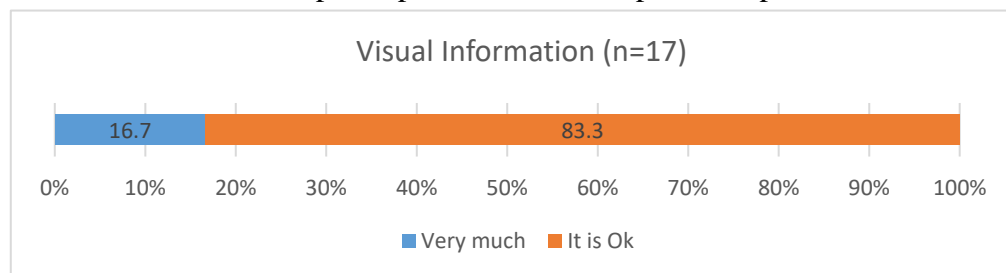
Figure 40 *Visual information.*

At the same time, 70.6% of the participants were happy with the visualised design ideas (Figure 42). The figure portrays the answers of the question 2 whether abstract produced models help participants to visualise their initial concepts or not. The answers indicates that most of the participants have managed to visualise their initial design concepts by the abstract 3D artefacts.
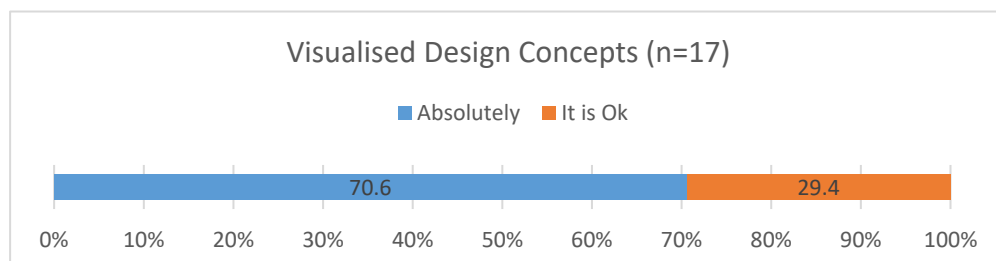
Figure 42 *Visualised design concepts.*

Altogether, 81.3% (n=17) of participants agree that collaboration happened between the designers (Figure 43), which is 55.1% (n=30) during the design consultation in Figure 36. Figure 43 accumulates the answers of the question 6 in the feedback survey. This indicates that the participants acknowledge the presence of collaboration. The evidence of design collaboration is explored elaborately later in Chapter 8.3.2, 'Analysis of VR Design Participation.' The produced design options are also ranked by experts, which is elaborated in the 'Expert Evaluation' section in Chapter 8.2.
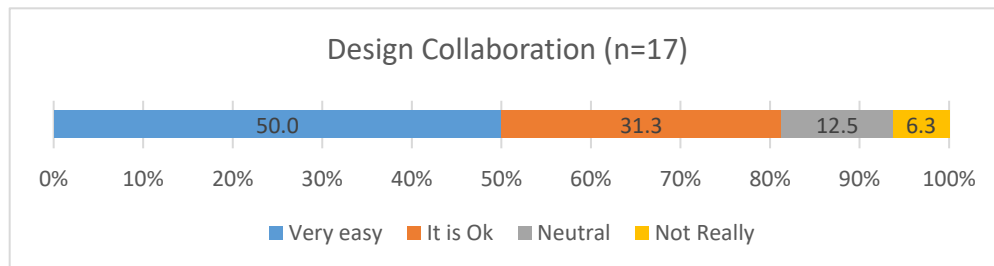
Figure 43 Design collaboration in VE experiment.*

Only four participants gave the answer of question 5. It was asking what should be changed/improved/added to the understanding. The answers were: "undo function in the instrument", "modelling features like subtraction and other materials", "other than visual: wind, water, noise" and " get comments instantly from groups to inform the design".

In summary, the survey results show that the VE design setup facilitated participants to take part in design collaboration in a visually informed environment despite not everyone being fully skilled with 3D modelling. We can speculate that the VE allows non-experts to perceive the design intent in a meaningful way, so that the collaboration also happens between them, which is analysed in Chapter 8.3.

8.1.3 Generated Designs

While the participants are designing, the visual information helps them to speculate on a different functional arrangement for the site. Participants proposed mixed-use commercial spaces with restaurants, parks, play centres, art pavilions, and a place for food trucks. Below, I illustrate 8 design options that were evaluated by the experts (Figure 43). The number of participants for

every design session varied, and also the design options. The produced design options are:

1. Option 1: Mixed-use urban park – 2 participants.
2. Option 2: Outdoor café and event space – 2 participants.
3. Option 3: Mixed-use urban park – 4 participants.
4. Option 4: Playground – 2 participants.
5. Option 5: Night-market, food stall, community event centre – 2 participants.
6. Option 6: Mixed-use retail space and café – 3 participants.
7. Option 7: Play centre – 2 participants.
8. Option 8: Urban park – 2 participants.

DESIGN 1 : MIXED-USE- URBAN PARK PERSPECTIVE VIEW AND TOP VIEW, TWO PARTICIPANTS

DESIGN 2 : OUTDOOR CAFE AND EVENT SPACE, PERSPECTIVE VIEW AND TOP VIEW, TWO PARTICIPANTS

DESIGN 3 : MIXED USE- URBAN PARK, PERSPECTIVE VIEW AND TOP VIEW, FOUR PARTICIPANTS

DESIGN 4 : PLAYGROUND, PERSPECTIVE VIEW AND TOP VIEW, TWO PARTICIPANTS

DESIGN 5 : NIGHT-MARKET, FOOD STALL, COMMUNITY EVENT CENTER, PERSPECTIVE VIEW AND TOP VIEW, TWO PARTCIPANTS

DESIGN 6 : MIXED USE- RETAIL AND CAFE PERSPECTIVE VIEW AND TOP VIEW, THREE PARTCIPANTS

DESIGN 7 : PLAY CENTER PERSPECTIVE VIEW AND TOP VIEW, TWO PARTCIPANTS

DESIGN 8 : URBAN PARK PERSPECTIVE VIEW AND TOP VIEW, TWO PARTCIPANTS

Figure 44 Generated urban design proposals.*

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Figure 45 illustrates the number of participants with 3D skills who produced the above design alternatives. It shows that, except for options 5 and 7, the rest of the design teams had at least one 3D skilled participant. However, all of them were able to produce design alternatives through VR collaboration.
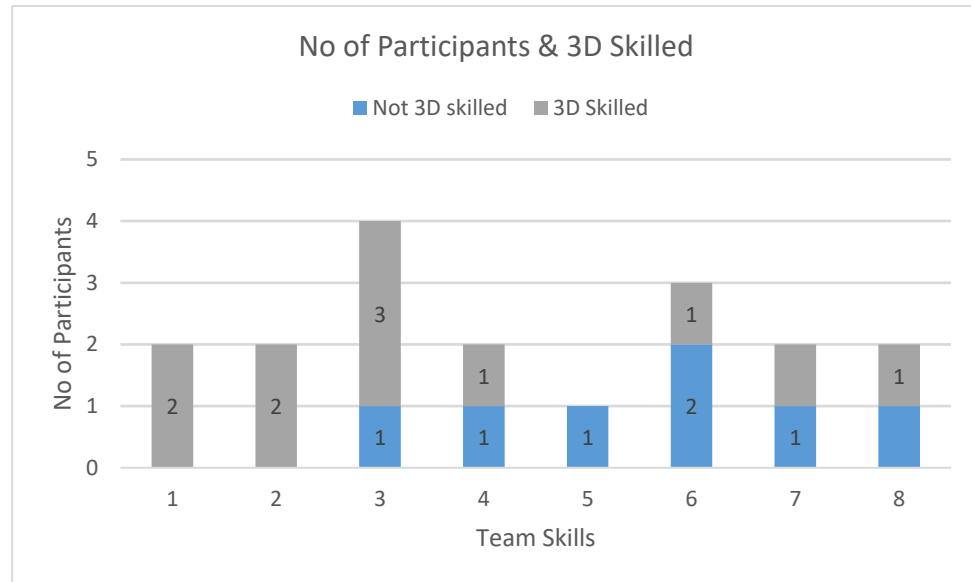
Figure 45* No of Participants and 3D skilled in produced design options.

8.2   Expert Evaluation

Two architects have evaluated the produced design ideas through a competitive scenario. The concept of scenarios offers a proven means to understand the competitors' strategies, capabilities, and likely future actions (Fahey, 1997). So, the experts ranked the generated urban design to understand the designers' interests in the quality of the spaces, functions, and aesthetics.

VE allows the experts to experience the design as though they are present sensually in the environment. It gives them the opportunity to evaluate the proposed urban form through experience. The experts inhabit as avatars in the environment.

In general, evaluating aesthetics in design is mainly a matter of grasping its sensuous qualities. Assessing aesthetic qualities does not mean that it exhausts all the different properties that design compasses, like

functionality and sustainability, but it does emphasise the function of design objects through sensual appealing on form and surface (Folkmann, 2010). It is also a vital matter to judge how design functions as a means of communication. Folkmann (2010) argues that it is not enough to ask what the meaning of a specific design is in the conceptual level, but to understand how it performs or reflects the meaning in its physical form. So, in this case, the evaluation on aesthetic reflects how the laypeople's proposed building form and its functions are communicated to the experts.

The experts evaluate the design options in a questionnaire. The evaluation criteria includes functionality, aesthetics, and experiential qualities of the design options. The intention is to identify whether the laypeople produced design ideas that could be communicated to them or not. The designs are judged by the proposed functions. The underlining purpose is to interpret laypeople's urban design ideas through expert eyes.

The experts give a mark from 1 to 5 for each design on every criteria, 1 as the lowest value and 5 as the highest value (Figure 46). The overview of the rating chart shows that not a single design option received a 1. This means that all of the design options are able to communicate ideas in terms of experiential, aesthetics, and functionality. It also suggests that all of the participants were successful in producing some sort of urban spatial objects in the VE.

According to the average ratings, design options 2 and 4 got the highest points (Figure 46). Design option 2, which was proposed as an outdoor café and event space, received maximum points in all attributes. This design carries further design details, which helps the experts to understand the spatial quality of the space. The participants considered the material properties of the designed building and outside seating. The experts virtually experienced the whole designed environment and read the concept of design quite easily compare to the others. Design option 2 was produced by two 3D skilled participants (Figure 45), but not professionals.

Design option 4, a playground, received the second-highest average points (Figure 46). During the design session, participants discussed a

playground for young people. The experts gave points on functionality. The IVE instrument facilitates the experts to experience the aesthetic and spatial quality of the space. The experts agreed that the spatial quality of the design can be read as a playground. Option 4 was produced by two participants, one of whom was skilled in 3D (Figure 45). However, the VE helped them to get into design discussion and generate meaningful design outcomes.

It seems that two 3D skilled designers who designed Design option 1 received fewer average points than one non-3D skilled designer who designed Design option 5. Again, two 3D skilled designers who designed Design option 2 received fewer average points than one non-3D skilled and one 3D skilled designer who designed Design option 4. This indicates that non-3D skilled people become close to 3D skilled people in design decision-making. They can understand and communicate with 3D skilled people in an efficient way to produce meaningful design outcomes. This also indicates that non-design expert stakeholders can collaborate with 3D skilled design experts. So, VE is facilitating the non-design expert stakeholders to take part in the design process.
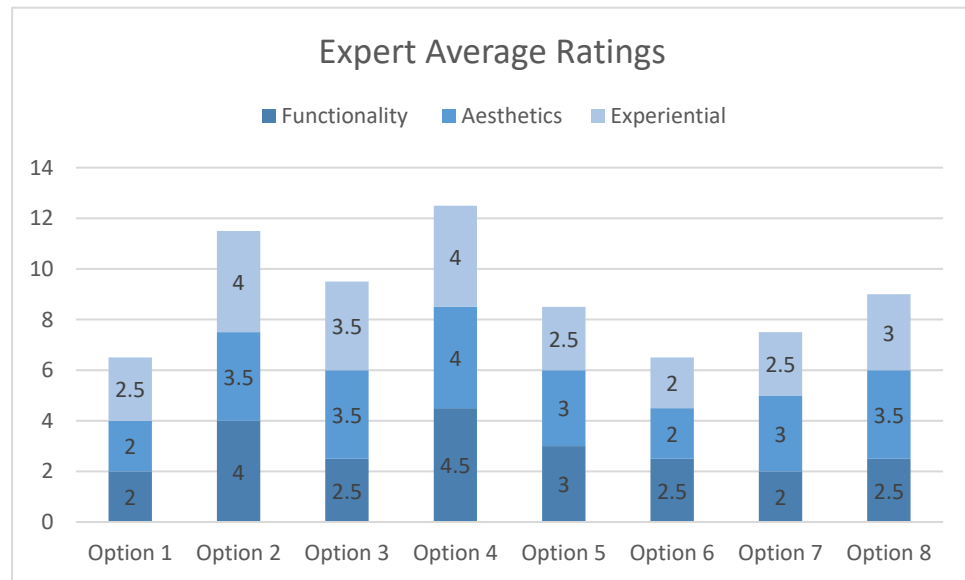
Figure 46 Average Ratings Attributes 1= Not at All, 2= Not Really, 3=Neutral, 4=It is OK, 5=Very Much.*

8.3   Protocol Analysis of VR Design Participation

The protocol analysis of the verbal conversation shows how the VE setup facilitated design communication between participants. The transcribed

conversation was coded to organise the data. The coding scheme was applied to investigate, analyse, and understand how designers and design participants communicate with the design instrument and control design ideas in VE. The design communication aspects were labelled with codes (i.e. a word or short phrase) aiming to find the categories of design communication and collaboration. It is necessary to mention that the methods are not theoretically neutral. The coding scheme rests on a set of assumptions about the general structure of the problem-solving processes and the verbal reporting process. In the context of my research, the transcribed conversation has been coded by two people according to the coding scheme and discussed in cases where dissimilarities came in. Some arbitration came to identify the reason for design interruption.

8.3.1 Coding Scheme

Based on Tsai et al. (2009), a coding scheme has been developed to evaluate virtual design communication and collaboration (Table 3). The four major categories of the scheme are 1. Communication control, 2. Design communication, 3. Social communication, and 4. Communication technology.

8.3.1.1   Communication Control

Communication Control has four subcategories: "Interruption by Design Members" (INT), "Interruption by Instrument" (INTS), "Handing-Over the Conversation" (HAN), and "Pause" during the communication (PAU). Tsai et al. (2009) have referred to Levinson (2001) works on defining coding for semantic conversation and handing over the conversation. The example shows that a speaker may hand the conversation over to another member by asking questions, such as "Isn't it?" or statements such as "You know," or by specifically naming the next speaker. Pause (PAU) is used if there is a temporary cessation of conversation during design collaboration in a virtual environment. We added the section INTS due to computer and software running interruptions.

8.3.1.2   *Design Communication*

The Design Communication scheme has been sub-categorised by Design Concept, Design Details, and Design Tasks. Design Concept includes how design ideas are handled during the design process such as "Introduction of Idea" (IDE), "Acceptance of Idea" (ACC), "Rejection of Idea" (REJ), "Clarification of Idea" (CLA), "Seek Clarification of Idea" (CLAS), "Development of Idea" (DEV), and "Evaluation of Idea" (EVA). CLAS was added after Tsai et al. (2009) when the designer asks questions about the design decision to inform the next design move. One recalls that only one participant is designing at a time as the other participant is providing feedback concurrently.

Design Detail includes the sub-categories "Discussion of Size" (VSZ), "Discussion of Shape" (VSP), "Discussion of Movement" (VSM), "Discussion of Type" (VST), "Discussion of Space" (VSS), and "Discussion of Colour/ Texture" (VCL/VTXT). VSZ and VSP have been added to evaluate the perceptual scaler understanding of 3D models produced in the virtual environment. In immersive 1:1 perspectival environment, the understanding of 3D building volumes initiates a different conversation on spatial understanding. Also, the developed interface allows the participant to jump or move in the virtual urban context. The VSM has been added to evaluate that perceptual movement in the virtual environment.

The coding scheme of Design Task includes "Task Questioning" (TKQ), "Agenda Referring" (AAR), "Instructing" (INS), and "Working Status" (VWS). TKQ is used when a design participant asks questions about their design tasks. AAR is used when a design member refers to the design agenda; in this case, the task of designing a mixed-use building block. VWS is used when a design member states what they are currently doing or have done, for example, "I have just finished the wall."

8.3.1.3 *Social Communication*

Social Communication comprises "Non-task-related Social Communication" (NRT) and "Joking" (JOK) in between conversations. This coding scheme documents the moments of conversation that are not related to design tasks.

8.3.1.4 *Communication Technology*

The coding scheme of Communication Technology consists of "VR Instrument" (VTL) and "Examining" (EXA). The VTL scheme is used when design participants discuss the use of the instrument. The EXA scheme documents when design participants discuss what they have done using the instrument.

Table 3 The coding scheme for VR collaboration (after Tsai et al. (2009) and Gabriel and Maher (2002))

Communication Control	Code	Description
Interruption by Design	INT	When a design member interrupts another member.
Interruption by Instrument	INTS	When a design member is interrupted by instrument functioning. E.g. wrong button / unexpected VR movement / instrument shut down.
Handing-Over the Conversation	HAN	Handing over the conversation from a design member to another member, possibly through questions or by specifically naming the next speaker.
Pause	PAU	Pausing during the communication.
Design Communication	Code	Description
Design Concept		*What is communicated*
Introduction of Idea	IDE	When a design member directly or indirectly introduces an idea.
Acceptance of Idea	ACC	When a design member accepts an idea of another member.

Rejection of Idea	REJ	When a design member does not accept an idea of another member.
Clarification of Idea	CLA	When a design member explains why the idea is appropriate.
Seek Clarification of Idea	CLAS	When a design member seeks clarification of another member's decision.
Development of Idea	DEV	When a design member further develops an idea.
Evaluation of Idea	EVA	When a design member spends time evaluating an idea.
Design Detail		*How the concept is created*
Discussion of Size	VSZ	When design members discuss the size of the 3D object / building.
Discussion of Shape	VSP	When design members discuss the shape of a 3D object / building.
Discussion of Movement	VSM	When design members move in the VR environment.
Discussion of Type	VST	When design members discuss building types.
Discussion of Space	VSS	When design members discuss spatial attributes. E.g. site entry, openness or closeness, orientation, etc.
Discussion of Colour/Texture	VCL/ VTXT	When design members discuss the colour and texture on a 3D building or on parts of it.
Design Task		*How the design is implemented*
Task Questioning	TKQ	When design members ask questions about their design task.
Agenda Referring	AAR	When design members refer to the agenda.
Instructing	INS	When a design member gives instruction to another member.
Working Status	VWS	When design members state what they are currently doing or what they have done. E.g. "I just finished the walls."

Social Communication	Code	Description
Non-task-related social communication	NRT	When design members talk about non-task-related things.
Joking	JOK	When a design member laughs or makes a joke.
Communication Technology	Code	Description
VR Instrument	VTL	When design members discuss the use of tools for design in the VR environment.
Examining	EXA	When a design member examines what has been done by using the instrument.

8.3.2 Analysis of VR Design Participation

After transcribing the audio recording in sentences, the analysis was done according to the coding scheme. The coded transcriptions have been provided in the appendix. The transcribed conversation was coded by two people according to the coding scheme and discussed in cases where dissimilarities came in. The research analyses conversations of a focused group comprised of three sessions for coding analysis.

8.3.2.1   *VR Collaboration*

The coding results show that 'design communication' is a dominant activity in VE design collaboration. For options 2, 4, and 7, 61.39%, 64.18%, and 43% respectively of the coding indicate that design communication happens during the design process (Figure 47). Designers communicate about tasks to design an urban form. They discuss building types, location, height, materials, orientation, etc. The virtual contextual understanding orients them to discuss those design tasks. Figure 48 also shows that 20.89%, 17.91%, and 25.67% of the conversation respectively for option 2, 4, and 7 happened due to social communication, which is a non-task related discussion between designers. This indicates that the instrument can facilitate the flow of non-relevant discussions such as jokes or other non-task related conversations. Moreover, 12.34%, 14.93%, and 8.67% of the conversation arose because of difficulties controlling the IVE instrument. The instrument is new for most of the designers. Also, familiarization with the instrument varies from designer to designer, which resulted in different percentages for Communication Control coding in the three different sessions. The results also differ in Communication Technology: 5.38%, 2.99%, and 22.67% respectively for option 2, 4, and 7. This means that the designers discuss using the instrument.
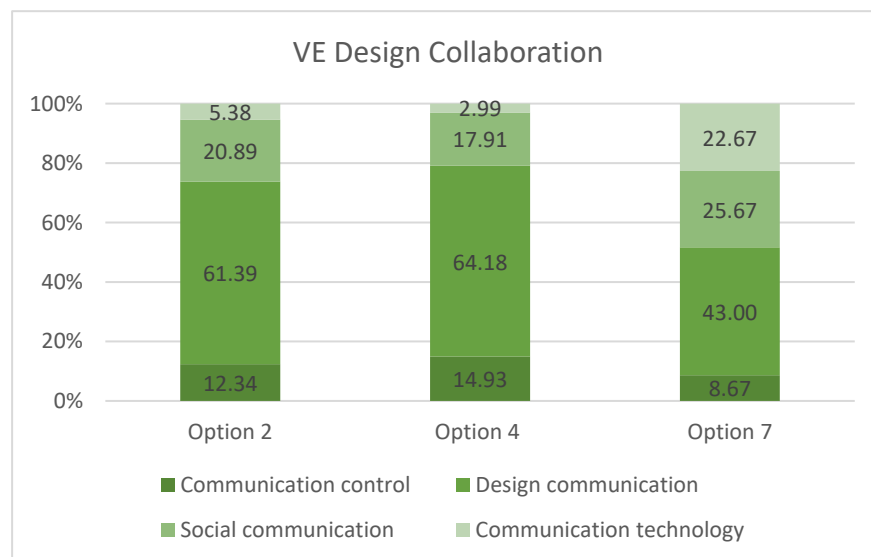
Figure 47* VE Design Collaboration.

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8.3.2.2   *Design Communication*

It seems that most of the design communication happens during design conceptualisation (Figure 48). For the three different sessions, 62.79%, 46.51%, and 62.37% of the conversation centres on introducing and discussing design concepts. This means that designers directly or indirectly present design ideas in an immersive virtual space via HMD and seek acceptance on those ideas from other participants via the 80-inch display screen. Designers talk about the introduction, acceptance, rejection, development, explanation, and evaluation of their ideas, often seeking clarification. A substantial percentage of coding shows that the designers discussed design details like the size, shape, and material of the 3D artefact/building as well as movement in the VE and the spatial experience. Comparatively, for option 2, 4, and 7, respectively 8.25%, 16.28%, and 37.98% of the conversations that take place are relevant to the design tasks, where participants ask questions, refer to the Task Agenda, instruct other participants, and state their working status. The percentage differences in each session indicate that the designers spend more time on developing design concepts compared to the design detail and the design task. It reflects that the instrument can instigate continuous design ideas. However, these differences may also be due to unfamiliarity with the instrument, as designers have to
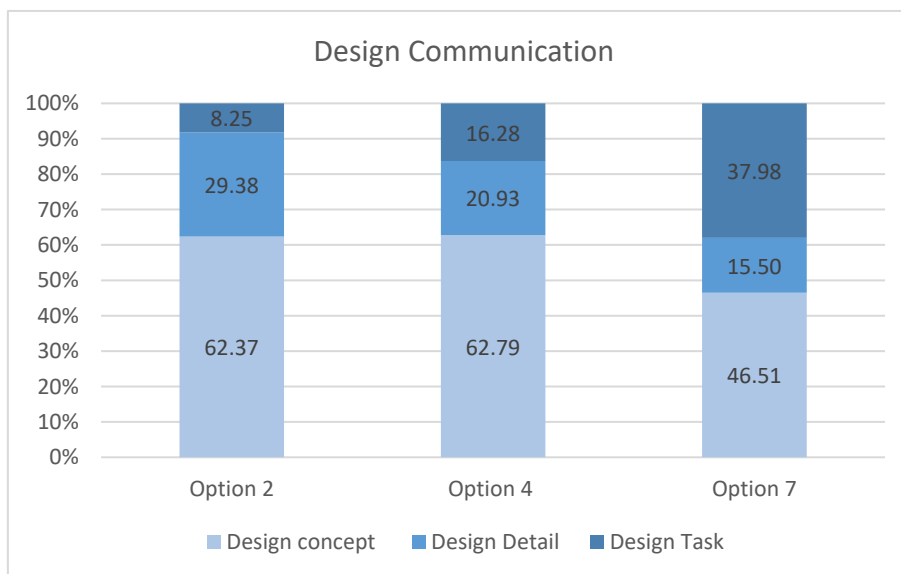
Figure 48 Design Communication.

spend most of their time initiating, accepting, rejecting, clarifying, developing, and evaluating design ideas.

8.3.2.3   Design Concept

The Design Concept coding results show that the participants spend most of their time accepting design ideas, then evaluating the ideas and introducing ideas. For the three sessions respectively, 33.89%, 29.63%, and 40% of the communication (during the design concept stage) focused on one member accepting the design idea of another member (Figure 49). This means that when Designer A in the IVE asked for consent from Designer B, who is monitoring design in the 2D display screen, design ideas were successfully communicated. Again, 8.26%, 25.93%, and 6.67% of design concept conversation happen when explaining the appropriateness of the design ideas. Similarly, 8.26%, 14.81%, and 26.67% of the design concept conversation respectively for option 2, 4, and 7 occurred when seeking clarification regarding another design member's decision. The conversation also takes place relating to the development of the design ideas. Table 4 shows one of the examples of such a conversation.

Table 4 Design conversation regarding pillar and columns.

Designers	Coding	Transcription
Designer A:	[JOK]	"...this side, yeah just cause it's easier eh." [laughter]
Designer B:	[CLA]	"I think it's because it's the corner of the room and it closes…"
Designer A:	[IDE]	"Ah, I've got an idea, let's make a pillar…"
Designer B:	[ACC]	"Oh yeah…"
Designer A:	[CLA]	"…here."
Designer B:	[VSP]	"…like columns..."

JOK = Non-task related Joke, CLA = Clarification of Idea, IDE = Introducing Idea, ACC = Acceptance of Idea, VSP = Discussion of Shape

In the conversion, the IVE designer gets an idea to make a pillar and starts to produce with the controller. Immediately, he gets consent from the fellow participant, who is seeing the 80-inch display screen. As soon as the designer finishes, the design participants can recognise the elements quite easily. This indicates that the instrument can facilitate design ideation, which can quite easily be communicated with other designers for clarification and acceptance.
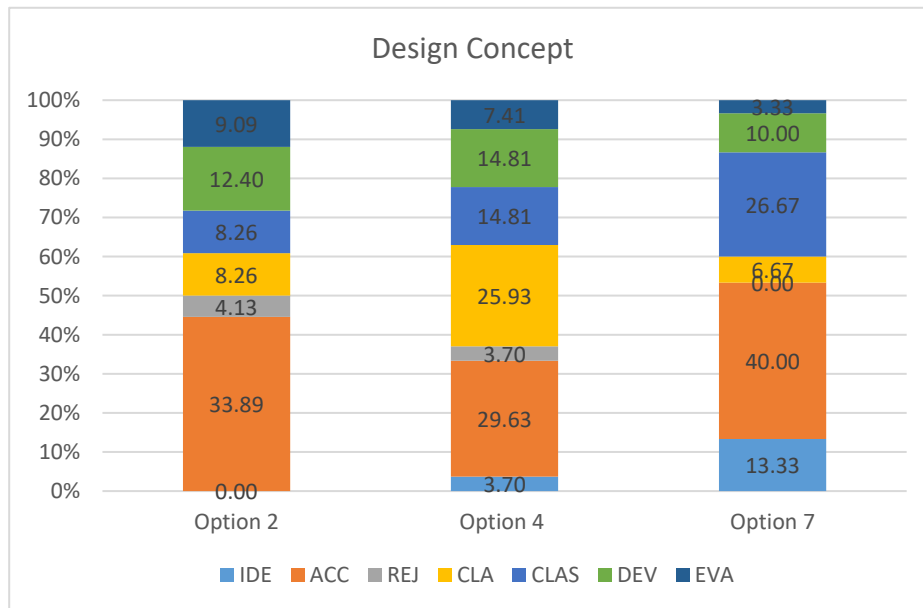
Figure 49* Design Concept.

8.3.2.4   *Design Detail*

In terms of how the concept is created, a detailed analysis of Design Details confirms that positive communication happened when discussing building shape, spaces, functional type, size, movement, and material texture. For options 2, 4, and 7, 3.51%, 32.33%, and 19.99% respectively of the conversations related to the size of the 3D artefacts or buildings (Figure 49). Similarly, 28.07%, 10.78%, and 5% of conversation about design details centred on the shape of the 3D artefacts or buildings. These kinds of conversations facilitate the designer's decision on the types of urban form they are proposing. Table 5 shows one of the examples of such a conversation.

Table 5 Design conversation on location and building features.

Designers	Time	Coding	Transcription
Designer B:	[08:11]	[VSS]	"What would you have under there?
		[VSS]	"Um, I guess you could put some café seating…"
Designer A:	[08:18]	[DEV]	"So it's out of the sun…"
Designer B:	[08:21]	[ACC]	"Yeah."
Designer A:	[08:23]	[IDE]	"Because it's Wellington, you probably want to figure out some wind breaks."
Designer B:	[08:28]	[DEV]	"Yeah, just a giant wall around the entire building."
Designer A:	[08:35]	[VSZ]	[laughs] "Yeah, just a really big wind break."
Designer B:	[08:43]	[EVA]	"But it's Karori, though, so it's not too windy."
Designer A:	[08:44]	[ACC]	"Yeah, true."

EVA = Evaluation of Idea, DEV = Development of Idea, IDE = Introducing Idea, VSZ = Discussion of Size, VSS = Discussion of Space, ACC = Acceptance of Idea.

The coding data also records conversations about movement in the VE. For options 2 and 7, respectively 45.61% and 19.99% of the conversations are about movement (Figure 50). This means that the designers are able to recognize Karori in the VE, and they can identify the contextual urban elements with the existing neighbourhood. They are also able to communicate about their movement in that artificial environment. In addition, the results of the coding analysis show that they spend time trying to understand the space with their proposed alternatives. For options 2, 4, and 7 respectively 17.54%, 32.33%, and 34.98% of the conversation relate to spatial attributes of the design. Table 6 shows such a conversation on spatial attributes of the site context.

Table 6 Design conversation on spatial attributes of the design

Designers	Coding	Transcription
Designer B:	[VSS]	"Okay, so, the driveway, is there a driveway? Is there an entrance?"
Designer A:	[CLAS]	"Yeah, is there a specific place that you might have a driveway?"
Designer B:	[VSS]	"Is there an existing one on the street? On this model there isn't but we'll make sure."
Designer A:	[VSS]	"Um, I think — what was it, from Campbell Street. I think this was an access way."

VSS = Discussion of Space, CLAS = Seek Clarification of Idea
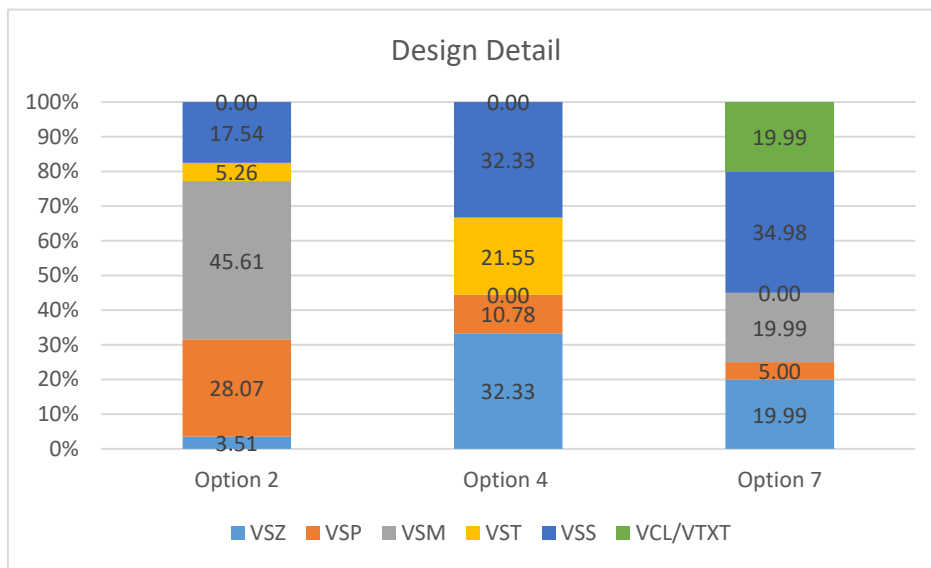
Figure 50 Design Detail.*

The conversation shows that the designers can understand the contextual features of the Karori neighbourhood and also those features are guiding them to locate themselves in the virtual neighbourhood. This indicates that there is a sense of presence in the VE, which propels the continuous flow of design conversation. The last two sentences show that the design members have discussed spatial attributes.

Again in Figure 49, almost 5.26 % and 21.55% respectively for option 2 and 4 indicates that they spend time deciding the function of the designed building. So, when a designer is proposing a certain building function while in the IVE, the other participant can visualise the function of the design. Deciding on the type of building depends on the common interests of the participants. In some cases, the decision on the types happened during the

design process, not at the beginning of the design. This means that the instrument is helping them to discover new types of spaces and functions while they are designing.

8.3.2.5   Design Task

Regarding the Design Task, most of the conversation centred on working status. 18.69%, 13.86%, and 57.12% of conversation respectively for option 2, 4, and 7 took place when designers stated what they had done or what they were doing (Figure 51). This shows the presence of design communication as the designers shared their working status. Similarly, 56.06%, 41.57%, and 30.60% of the task-related conversation focused on instruction. Such conversations occur when a designer gives any design instruction to the other designer. Table 7 shows such an example, where Designer B frequently instructed Designer A on a certain design task.

Table 7 A conversion on space and instruction.

Designers	Coding	Transcription
Designer B:	[ACC]	"Ah, that's fine."
Designer A:	[INS]	"So maybe pull it back a bit?"
Designer B:	[INS]	"Nah, nah, take it all the way down, I reckon."
Designer A:	[INS]	"No, I mean, pull it closer to where I'm standing."

VSS = Discussion of Space, INS = Instructing

The conversation arises from questions relating to the task. In Chapter 7.3.1, I discuss that the design task is to design a functional building on the corner plot of Campbell Street. The participants are informed that the WCC is looking at a building proposal that can make the Karori Centre more vibrant. As multiple participants are designing together, they ask task-related questions to themselves. 24.92%, 27.72%, and 6.12% of conversations were on task questioning for option 2, 4, and 7 respectively. Table 8 shows such a conversation on the design task.

Table 8 An example of a design task conversation.

Designers	Coding	Transcription
Designer A:	[TKQ]	"Did you want to do two separate buildings?"
Designer B:	[REJ]	"Um, no."

	[INS]	
	[PAU]	
Designer A:	[ACC]	"Oh there you go — ah, that's cool."
Designer B:	[INS]	"Actually, you need some things that make sure it won't fall down."
Designer A:	[JOK]	"Some physics?"

TKQ = Task Questioning, INS = Instructing, PAU = Pause, ACC = Acceptance of Idea
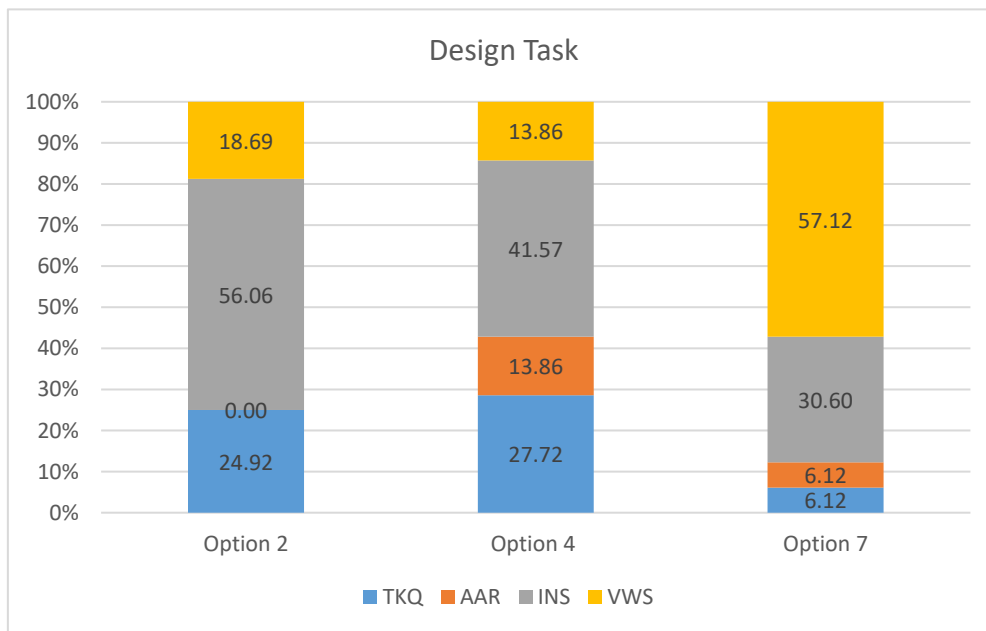
Figure 51 Design Task.*

8.3.2.6   Social Communication

Figure 52 shows that the participants spent a significant amount of time on non-task related social communication and joking during the design sessions. This indicates that there is a continuity of conversation during the design session, which occasionally gives rise to witty talk. For option 2, 4, and 7 respectively 24.24%, 83.33%, and 19.48% of Social Communication are coded as Joking. This usually happened when a design member laughed or joked. Similarly, 75.76%, 16.67%, and 80.52% of social communication conversation for option 2, 4, and 7 respectively are non-task related. This

means that the VE setup facilitates the flow of conversation during the design process.
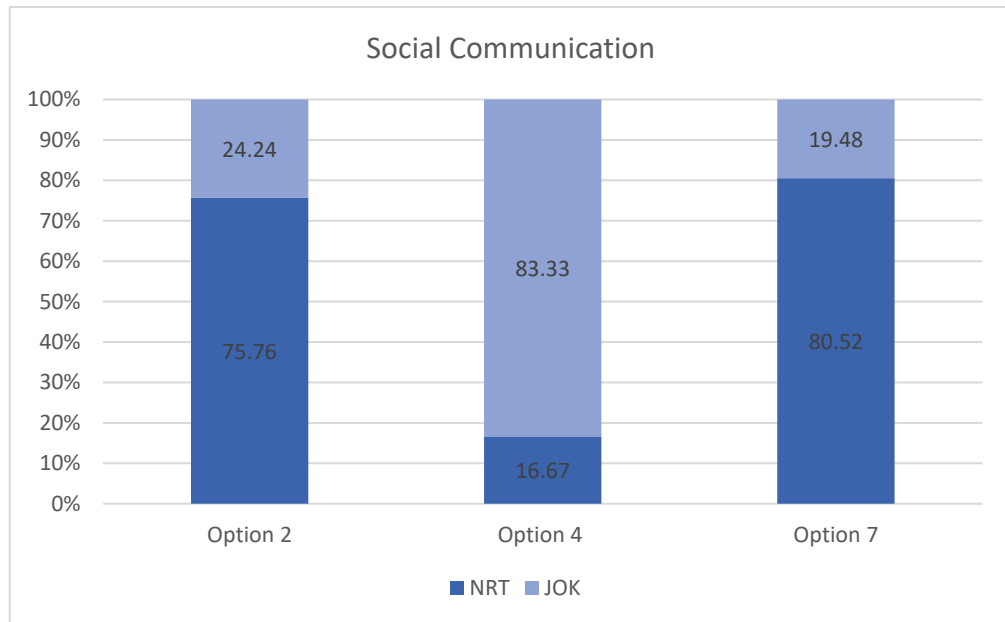
Figure 52 Social Communication.*

8.3.2.7 *Communication Control*

The lack of familiarity with the VR instrument interrupts the design communication substantially. Design interruption occurs due to pressing the wrong button or from an unexpected VE movement. Almost 76.94%, 24.25%, and 80.74% of communication conversation respectively for option 2, 4, and 7 happened due to the Interruption by Instrument (Figure 53). Also, 7.69%,
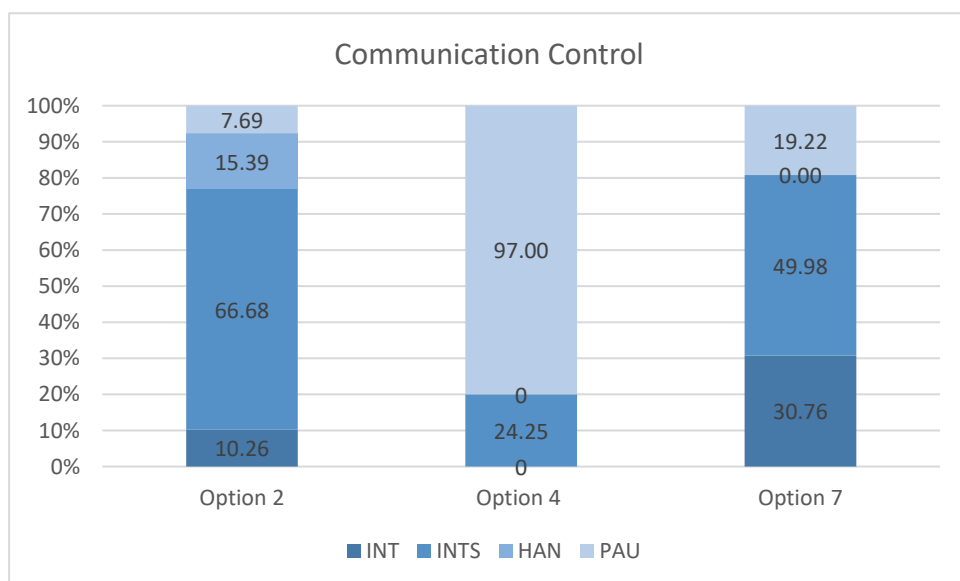
Figure 53 Communication Control.*

97%, and 19.22% of the coding respectively for the same design sessions indicates that there are incidents of Pause during the design communication.

Chapter 9 Discussion

This chapter discusses the research focused on five different themes: firstly, on the four core schemes of the protocol analysis, Design Communication, Social Communication, Communication Control and Communication Technology; secondly, design interaction and collaboration; thirdly, the VE experiment and expert's role; fourthly, layperson's participation; and finally, how this VE design setup might be used in the context of neighbourhood design in New Zealand. The chapter concludes by discussing this thesis's contribution to the knowledge base on urban design engagement processes.

9.1   VR Design Communication

I discuss the four primary coding schemes of protocol analysis, Design Communication, Social Communication, Communication Control, and Communication Technology. The protocol analysis demonstrates that the spontaneous exchange of perceptual understanding in a virtually informed environment along with verbal conversation can produce meaningful design outcomes.

9.1.1 Design Communication

The conversations between the participants are relevant to design intervention, are context-related, and arise naturally from the synchronized setup of design engagements and task distribution among the participants. *Designer A* acts in the immersive world via HMDs, and *Designer B* provides verbal feedback via the 80-inch display screen. Both designers are laypeople. In between snippets of conversation, the designers generate 3D urban forms that provide visual feedback to facilitate further discourse. *Designer A* acts due to the interface which supports Gaver (1991) concept of 'technological affordance', where the generated 3D artefacts possess the perceived properties to influence subsequent design actions. Subsequently, *Designer B* gets visual feedback of the generated 3D artefacts as a representation of new design ideas.

The results reiterate that verbal communication can perform effectively alongside non-verbal communication through the generation of 3D artefacts. Designers spend time developing the design concept, discussing design detail, and referring to the design task. Design discussions advance via the generation of visual information, which instigates the next design action.

9.1.1.1 Thinking Process

My research shows that the thinking process is driven by geometric thinking with the generation of 3D artefacts instead of conventional reasoning, which aligns with Chan (2011) arguments on perception and representation. The 3D representations created in VE are associated with a real-world problem and are generated mental images reflected from perception. This cognitive phenomenon of perception provides meanings to the generated 3D artefacts. It also occurs due to the quality of the perceptual awareness of the VE. The conversation happened in a non-restricted way, therefore the designers are spontaneous in their design actions. Such verbal exchange proceeds towards the design discussion on conceiving the urban form.

The instrument generates 3D artefacts in the VE as representations of urban forms. Design is a representation of one's mind to communicate ideas

with another mind through an external presentation, and language is a set or system of such symbols as used by people to communicate intelligibly with one another. So the design language means a set of symbols that are used to convey one's thoughts to others. In this case, the design language built upon experience rather than an aesthetics of form. A non-verbal symbol is used to communicate design ideas. The VE provides an instantaneous perceptual understanding of the Karori context as a canvas to generate urban forms.

9.1.1.2 Verbal Exchange of Ideas

The verbal exchange helps to initiate ideas in the early stage of design development (Luck, 2003). It is an iterative process to comprehend the consequence of the verbal exchange of ideas. The research facilitates that sort of verbal exchange of design ideas, and they seem quite successfully communicated with fellow designers. The verbal exchange of design ideas is spontaneous and clear. This can be seen from the protocol analysis of Chapter 8.3.2. Particularly, Figure 51 shows that the designers have a frequent non-task related conversation, which ensures the evidence of verbal exchange and the familiarization of the design engagement. This occurs due to the easy affordance of the VR instrument and the experiment setup. The visual has a more powerful impact than just speaking about design ideas. The verbal exchange coupled with the simultaneous generation of 3D artefacts instigates new design ideas.

9.1.1.3 Sense-Making Communication

In the experiment, the communication process acts in a complex iterative process in which meanings of conversation are continually constructed and destroyed as a sense-making communication through new design actions in the VE. Sense-making offers circumstances of the interplay of actions and interrelation of choices through plausible images to rationalize what people are doing (Weick et al., 2005). It helps to organize the meaning of actions. It involves communication through interactive talk and draws on the resources of language in order to formulate and exchange through talk, which symbolically encodes representations of these circumstances. From that perspective, the generation of 3D artefacts and their representations facilitate

senses to interpret design actions among the participants. Again, according to Bannon et al. (2018), design actions have to be interpreted and situated within a purposeful collaborative design activity, which is mediated by VR tools. The results of the protocol analysis in Chapter 8.3.2 show that design actions occur with the situated purpose of the design collaboration. Akin to Schnabel (2011) work, the study confirms that collaboration and designing within VE happen due to efficient verbal and visual communication. The designers explore the spatial impact of their urban design proposals in relation to existing surroundings and building forms.

9.1.1.4 *Suspension of Disbelief*

The representation of the Karori neighbourhood in the VE embodies the perceptual understanding of the context for designers to orient in the environment. This notion of accepting VE as real also supports McCullough (2004) ideas that VE allows participants to suspend their disbelief of not being present in reality. *Designers A* are feeling the sense of self-location (Kilteni et al., 2012) through a perceptual understanding of the environment, which becomes non-real and offers easy navigation in the IVE. And, due to the sense of agency, the designers become active in the environment. *Designers A* feel the sense of body ownership from the sensorial interaction with the instrument. Again, designers' personal contextual experience brings knowledge of reality during the design discussion, which is one of the qualities of the participatory design process.

9.1.1.5 *Exchange of Visual Information*

Aligning with Brown (2003) argument the graphical representation of the VE provides the recognisable visual information for 3D interpretation. The elements of the VE are assembled, composed, and perceived during the design process. These acts generate the state of consciousness to interpret the virtual representation.

Again, the results of the protocol analysis show that the designers shared their perceptual understanding of the urban spaces in the design process. The designers have different modes of perceptual understanding, as

they are receiving information in two different media: immersive VR and 2D display. The designers immerse into design discourse through the frequent insertion of design ideas and discussing other's ideas. The virtual perceptual environment helps them to initiate new ideas and join the conversation. The immersive urban perceptual information and the easy production of 3D artefacts orient the designer to initiate design ideas. Simultaneously, designers can provide verbal feedback on visual ideas.

9.1.2 Social Communication

The results of protocol analysis show that the design conversation extended beyond the task-related conversation. It indicates the continuity of the conversation as a natural flow. The design discussion happens to design an urban form. The discussions that occurred went beyond building shapes, size, spaces, and types. Sometimes the designers talked about the impact of new design in terms of environment, social cohesion, and inclusivity of the neighbourhood. The dialogue exchange allowed subject-specific knowledge transfer among the participants. Sometimes, the designers tell jokes to each other, which shows the natural flow of the design conversation.

9.1.3 Communication Control and Communication Technology

In Chapter 8.3.2.7, the analysis of communication control indicates there are design interruptions by the designers. This happens when a design member is interrupted by another member, instrument functioning interrupted, the conversation is handed over, or pauses occur during the sessions. The interruption by the instrument also indicates that the design members face interruption due to the unfamiliarity of the VR instrument. However, despite the interruption of the VR instrument, the result of communication technology shows that designers communicated effectively.

9.2   *Design Interaction and Collaboration*

The VE experiment setup is designed to produce iterative 3D artefacts through design interaction and collaboration. Below, I discuss how the concept of design interaction and collaboration existed in the experiment.

9.2.1 Design Interaction

Design imagination happens due to the contextual information, iterative production of 3D artefacts, and the user-friendly nature of the VE experiment setup. The continuity of design production can be traced in the verbal conversation, which is analysed through protocol analysis in Chapter 8.3.2. The designers form internal mental models of themselves by interacting with the environment, with others, and with the artefacts of the technology. According to Norman (1988), such a process of mental modelling is one kind of interaction. In the line of Norman's concept, the employed immersive iterative 3D artefacts provide predictive and explanatory power for understanding the interaction.

The design discussion progressed when every action of a designer produced visual information and initiated the next level of design action. This can only be done if the design communication media provide continuous visual feedback to the designer. This informs successful design interaction. Following Fuchs et al. (2011) interaction techniques for Virtual Behavioural Primitives, the design interaction occurs in all of the four categories, where the designers observe, move, act, and communicate with others and also with the application for its virtual interface. This is the result of successful completion of the loop between "perception, cognition, and action." Also, this aligns with Brown (2003) arguments that interaction between the designer and graphical physical descriptions is a necessary part of an effective design process. Here, the designers' ability to produce urban forms meet the performance goals to a certain level including visual, technical, cultural, and social.

The success of the design communication depends on the design task and the procedure of the VE experiment. The strategy aligns with Cross and Cross (1995, p. 144) statement, '*In design, it is not normal to have a clear and immediately apparent problem given as the task, in the way that is normal in other problem-solving studies.*' The presence of design interaction with the VE experiment facilitates design communication between human-computer and human-human. Each design interaction works through its affordances and

constraints. The design task and the set-up of the experiment orients designers to create building forms. Designers mutually construct conversation moment-by-moment as a form of interactivity through their use of verbal exchange and design action.

The employed VE design process reflects through action and negotiation between designers. According to Schön (1983), in design practice, the design process is fluid and determined upon the designers' knowledge and experience, where designers continuously reflect on their strategies and actions ('make moves') to change the design situation. VE design communication happens due to the presence of design interactions. It is the result of human-computer interactions, where the computer is producing 3D artefacts in the VE and eventually provides visual feedback to take design actions and initiates design discussion among designers. The assigned design tasks helped the designers to formulate new design alternatives for the Karori Centre.

9.2.2 Design Collaboration

Collaborative design is a complex mechanism where an individual participates through discussion. My research reduces the flexibility of choices by setting different roles for different designers. The experiment set up provides visual information and perception to the designers to make collaborative design decisions. Design collaboration on the same task has influenced the level of design acceptability despite not representing the real scenario. This means that the employed collaboration techniques deepen the level of information accessed through sensitising the participants to a wishful design discussion, which supports Sanders and Stappers (2008) concept of tools in participatory design approach.

9.2.2.1 Design Collaboration between the Designers

Both the result of the protocol analysis in Chapter 8.3.2 and the feedback survey on virtual design in Chapter 8.1.2 show that design collaboration happened between the designers. The conversation between the designers is relevant to design intervention, which is also context related. In Figure 46, it

is illustrated quite clearly that VR collaboration happened through design and social communication. It has occurred due to the synchronised setup of design experiments and the task distribution among the designers. Both the *Designers A* and *B* are engaged in design conversation. In between their conversation, the representation of 3D artefacts provides visual feedback to continue the discourse. It supports the NSC-BBHTC aims to establish collaboration between stakeholders and citizen through co-created innovative tools. Yet, some discrepancy occurs because of technological disruption. The results of the protocol analysis also show that verbal communication can produce more significant conclusions along with non-verbal communication supported by 3D artefacts to generate meaningful urban design outcomes.

Besides, in the real world situation, the designers play negotiating roles to come into the level of mutual understanding. *Designer B* allows *Designer A* to take design actions and simultaneously negotiate through conversation. Their acceptability of each other opinions develops by workspace awareness as well as their affiliation to the same community. Aligning with Gutwin and Greenberg (1998), workspace awareness in a co-design process brings power to the designers. It achieves through consequential communication and feedback. The result of the IVE experiment shows that the designers have consequential communication verbally. The feedback produces when the artefacts are manipulated by *Designer A* and provided clues of that manipulation to *Designer B*.

9.2.2.2 *One-way Consultation to Two-way Design Collaboration*

The surveys generated information about the respondents' personal perceptions of their experience in design consultations and VE experiments. These gave the designers the ability to express their personal preferences in the design process without being affected by group pressures and influences. Each answer was an expression of their personal choice. Chapter 7 reports a survey on the existing consultation process that happened on 7th November 2018, where the design communication happens only from one direction, which corresponds to Mattelmäki and Visser (2011) first direction of designer

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and user engagement. According to the article, the role of the user is a one direction communication where a user's voice needs to be heard (Figure 8). This direction is not co-design, and that is why this approach used to be used a lot in the field of urban design. However, after the virtual engagement, the survey results in Chapter 8.1.2 show that the users experienced design together, which indicates two-way design communication. It again supports Mattelmäki and Visser (2011) third direction of design communication, where the users and designers exchange ideas and envision a collaborative creation process. The concept is based on Sanders (2002) arguments of collective creativity, which is more powerful than individual creativity, though she refers to the collaborative works between designers and everyday people as a means of co-creativity.

9.3   Expert's Role and Designer's Role

The expert plays the roles of task setting for design engagement, evaluating the generated design and facilitating the design collaboration between laypeople. Developing the VE experiment setup also requires the understanding of a user's experience. This section discusses the roles of experts and designers in the study.

9.3.1 Expert's Role

The research offers a method to embrace laypeople in sharing design ideas on their neighbourhood in a communication structure developed by an expert. For the sake of the research, I have to act as a researcher and an expert. As a researcher, I have developed the IVE experiment setup and the instrument, and as an expert, develop the design task.

9.3.1.1   As an Expert

Current urban design practices include experts at the beginning stage of the design process. Experts bring developed design ideas to the non-experts. They adopt different communication media to present their works. On the contrary, in the participatory urban design process, the non-experts produce meaningful design outcomes through the process of participation with relevant tools and techniques. Experts develop the participatory objectives, goals, tasks, tools

and techniques at the early stage of the design process. But due to the lack of right communicative tool during the design discussion process, the design ideas related to urban form stays hidden in assumptions. Besides, most often, the discussion ends without any results. If the process manages to come to any meaningful outcome, it takes significant time. In the study, experts come at the end to recognise and evaluate the designs (Figure 54). They can understand laypeople's complex design outcome without any help. Non-experts take design decision by themselves at the initial stage of the process. They bring their collaborative design decisions to the experts. The perceptual quality of the 3D artefacts develops meaning to the generated design ideas, which experts can interpret and evaluate. So, in that sense, the expert role is shifting from the middle to end; they are not coming at the beginning stage of the design generation.
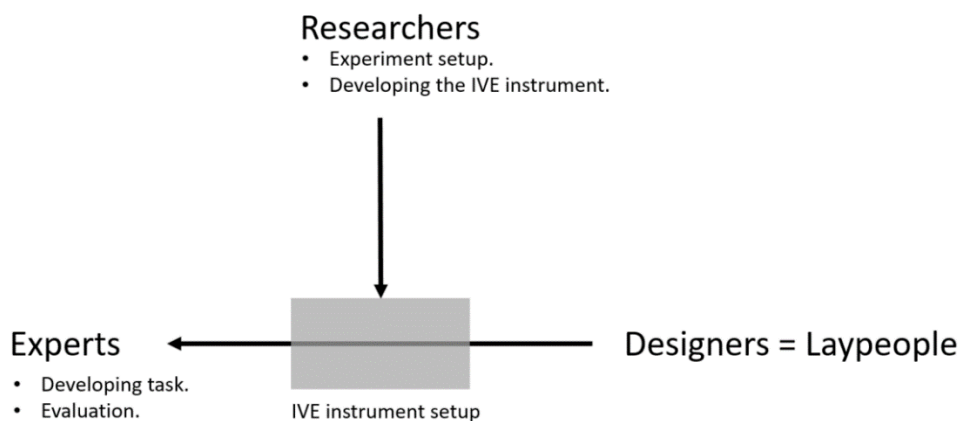
Figure 54* Roles of researchers and experts.

I set the design task understanding the scope of the instruments and the interest of the local community. The answers to the survey 1 show that they preferred to design in a more informed and perceivable environment. The design task set based on the report of WCC consultation. These issues helped me to set the framework of the design experiment event on the site. The participants got the chance to design and visualise their imagination together. The design engagement let them act as designers for their own environment. It seems the roles of designers and laypeople are coming to a level where the laypeople can create and propose design ideas through collaboration with fellow designers.

Besides, laypeople can participate in the design process without any set task from the experts if they are aware of their tasks by themselves. The flexible nature of generating 3D artefacts can encourage laypeople to set any other design tasks relevant to urban form. Obviously, for other types of design task, research is required to develop another design instrument compatible with the new design task.

In one stage of the study, the experts are invited to evaluate the laypeople's generated designs. They rank the outcomes through competition format, which allows them to find the potential urban design alternatives for future development. This procedure ensures the transparency of the design selections. Besides, the evaluation step also supports Sanders et al. (2010, p. 195) argument that *"within participatory design have given more concern to how non-designers can articulate design proposals in such a way that these can provide a starting point for subsequent professional development work"*. In the study, the expert evaluation on generated design ideas from the laypeople can be considered as a starting point for subsequent future development.

9.3.1.2   As a Reseacher

The experiment setup is developed considering the issues related to the Karori people's interests on their future City Centre, WCC's interests on urban redevelopment, selecting the VR instrument, understanding the VR instrument's capability of design interactions, the possible types of 3D artefacts that the VE can generate, modifying the VE environment, picking the task site, designing the experiment unit setup and designing the steps of design communication between participants. The procedure of design experiment helps to facilitate design discourse through visual and verbal interaction. So, the whole process demonstrates an expert's action on developing a system which depends on the active participation of laypeople leads to producing bottom-up design ideas.

Developing computation instruments to assist the laypeople in design participation is a crucial part of this research. The VR instrument has to be equipped enough to generate intuitive 3D artefacts. The perceptual

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understanding should facilitate enough situated cognition to accept the VE as representing real urban forms, so the non-experts can easily participate in design production. Aligning with the concept of Carpo (2011), such a computational instrument removes the role of professional authorship, as a non-expert becomes a design generator. The employed VR instrument generates instantaneous stimuli of 3D artefacts with the presence of perceptual understanding of the VE. The operative attributes of the instrument are spontaneous in design ideation and generation, which helps the laypeople to design proactively in the environment.

9.3.2 Designer's Role

As I discussed earlier, in current urban design practices, non-experts come at the end of the design process. Experts represent the design concepts with communicative artefacts like drawings, renderings or models to non-experts to interpret the ideas. On the contrary, this research demonstrates a participatory way with the support of VE, where the non-experts can produce 3D meaningful artefacts by themselves. The study shows a method of how non-experts bring the initial stage design concepts to the experts. Besides, the participants in the VE experiment belong to the same community. The affiliation of their awareness allows them to communicate in the same language and the concurrent generation of 3D artefacts that places them to the negotiated level to continue the flow of conversation. Also, the design conversation builds confidence to the designers to interpret the design content. The process of decision-making happens in a collaborative manner where they act as a team. So, the design process builds the capacity among the designers to control design decisions. Besides, the process reduces the chances of conflict as it requires continuous acceptance of feedback from co-designers to continue the conversation and brings the feeling of ownership on their decisions as well.

9.4 Laypeople's Participation

Here I discuss the laypeople's participation in terms of liberating them to make design decisions and increasing citizen involvement in the urban design process.

9.4.1 Liberating Design Decision

Design participation also can be seen as creating space for discussion through liberating speech. The VE setup liberates the laypeople to make design decisions. The problem of the conventional consultation process is that it is performed on a certain expected functionality, where the participants have limited room to convey their design ideas (Petrescu, 2005), which is revealed through the preliminary questionnaire results in Chapter 8.1.1. This is primarily due to a lack of suitable design communication tools. The way participation is organised has consequences for the results of the discussion. In that case, the research experiment setup liberates the laypeople to generate their design options by themselves.

The design discussion process passes through the level of negotiation. The coded analysis of the transcription shows that there are incidences of acceptance of proposed design ideas between the designers and also incidences of rejection of design ideas. Through the process of design discourse, the laypeople come to a consensus to accept certain design features. Such a design discussion supports laypeople's direct involvement in the design and shows that the design decision-making process has a positive influence on generating continued insight and knowledge (Luck, 2003). It also shows that during the participation time there has been a maturation of the laypeople's thinking in the design process, which occurred due to the iterative generation of urban form.

The VE experiment leverages laypeople to produce design ideas on urban forms, types, and locations. They bring new insight to the initial stage of the building form design, including its functional distributions, and also with minute detail like location, orientation, and material.

9.4.2 Greater Citizen Involvement

Greater citizen involvement in urban design and decision making is needed to increase knowledge about complex problems (von Heland et al., 2015). The audience has to relate to the proposal. Usually, the outcome of participation is not predictable. In such a case, one single voice cannot change

the situation. In contrast to that, the employed virtual instrument allows multiple stakeholders to exchange their voices. In the research, the novel technology is managed to engage diversified citizen participation to solve a rational problem. The experiment set up brings creative ideas and original views of citizens to neighbourhood design. The research develops an equal platform for engaging community people in urban design. Moreover, in the design process, an individual user becomes a member of the design team, which supports Dulgeroglu (1977) arguments on the user's participation in design decision-making. The citizens are making decisions on conflicting issues of the design problem together. Meaningful design outcomes develop by dealing with the design task and negotiating through the conversation. The flow of conversation reflects citizens views on visualising future neighbiurhood, which has revealed through protocol analysis.

The VE design participation might be seen as direct public involvement in decision-making processes, where citizens share urban design decisions that determine the quality and direction of their lives. The citizens were well informed about the reasons behind the proposals and be able to respond to them in the technical language of professional designers. They participate in their wish and express their urban design desire developed through negotiation. They discuss potential urban form as added perceptual value to the representation of the generated 3D artefacts. The decision on urban form represents the future direction of their lives in the neighbourhood. Several suggestions have come on the types of urban form, and all of them develops from the concern of having a better living in the Karori neighbourhood.

9.5   Neighbourhood Design in New Zealand

Here, I discuss how the research initiates the possibility to integrate the approach into New Zealand's urban design policy.

The result of the protocol analysis and the generated design proposals show meaningful design communication to the future development of Karori. Figure 50 shows that the design discourse happened on types of spaces and sizes. Similarly, Chapter 8.1.3 illustrates differences in design output and

types of interventions. The laypeople from the community expressed their individual interests to future development in the Karori Centre. The virtual instrument leveraged them to express their interest in their neighbourhood.

9.5.1 Aligning with NSC-BBHTC Challenge

Aspects of the NSC-BBHTC challenge seek liveable and well-designed neighbourhoods by investigating better land-use decision making through collaboration with stakeholders. In that sense, the employed VR instrument allows non-expert stakeholders to take part in land-use decision making along with an enhanced spatial understanding of their proposed urban form.

The research supports Haarhoff (2016) arguments, who is a principal investigator in the same NSC-BBHTC challenge. He states that collaborative urban design production plays a crucial role in shaping New Zealand's urban places to ensure the community's 'well-being'. Allen (2018) also argues for joint decision making and citizen-planner partnerships as the foundation of successful neighbourhoods. In urban design practice, the necessity of cooperation between local stakeholders, communities, and business involvement in decision making and place-shaping requires policy interventions. A healthier neighbourhood can come into fruition with a successful collaboration of those organizations in a cost-effective and meaningful way. In that sense, my research's effective inclusion of the laypeople from a local community in the urban design decision-making process can be added to the policy to shape New Zealand's neighbourhoods.

The mission of NSC-BBHTC is "Manaaki Tangata: Co-created innovative research that helps transform people's dwellings into homes and communities that are *hospitable*, *productive* and *protective*" (NSC, 2017), which the study has considered in a certain extent. The challenge moto is co-created by laypeople for design collaboration and participation in urban design. An innovative computational way has employed for citizens' participation in the neighbourhood design. The approach is '*hospitable*,' involving local community people in design collaboration and the participation process (Table 9). It is '*productive*' by producing meaningful urban forms with the spontaneous participation of local people. Finally, it is

'*protective*' through involving local people, which brings their cultural value in the design discourse. The research demonstrates laypeople's design participation in an urban design process, which shows an innovative way to re-establish collaboration between stakeholders and citizens in designing New Zealand's future neighbourhoods.

Table 9 Aligning with NSC-BBHTC.

Mission of NSC-BBHTC	My Research
Co-creating	Designing collaboration and co-creation of urban forms by local people.
Innovative research	Employing an immersive computation method.
Hospitable	Including local people in urban design collaboration and participation.
Productive	Engaging local people in the urban design process and generating urban scenarios.
Protective	Engaging local people in design collaboration.

9.5.2 Towards Urban Design Policy

New Zealand's government has action policy and principles for urban designers by suggesting community participatory design approaches to develop inclusive urban design proposals (Gunder, 2011; NSC, 2017). It destines to encourage community involvement and informs new design initiatives to them. It also suggests using interactive visual displays, which can be used to encourage wide participation through interaction between participants as they respond to other participants' decisions. My research can be considered as a new avenue to include an immersive virtual instrument as a tool to engage a community in an urban design process. The produced designs, discussed in Chapter 8.1.3, show that despite having different interests in design, the VE setup unified them to come to a potential agreement. The proposed building function varies significantly. Drawing on Latour and Porter (1996), the explored visualisation technique can be

instrumental in preparing individuals as well as the public to perceive and communicate about reality, which establishes values and prescribes a specific solution and design policy. As such, a design engagement encourages more democratic participation in neighbourhood design, so it shows the benefit of including VE engagement in urban design policy. Besides, the urban design toolkit (Mfe.govt.nz, 2009) encourages the use of interactive visualisation tools to engage people, where such sophisticated collaborative generation of 3D artefacts can facilitate seamless design communication on special understandings. The dissertation may influence the governmental body to include VE assisted participatory design approach to shape New Zealand's future neighbourhood.

According to the Resource Management Act (RMA) on urban planning and design of the Ministry of Environment in "Building Competitive Cities: Reform of the Urban and Infrastructure Planning System A Technical Working Paper," the complex urban planning system creates a lack of alignment between spending, policy, regulation, and development (Mfe.govt.nz, 2019b). It means that the current planning system is not able to effectively engage stakeholders in decision making on the infrastructure development process in the right place at the right times. It indicates the policy does not support quality urban development and value for money. The report also argues that the current urban design system has a lack of consistency in decisions in terms of providing quality urban development, which requires effective interaction and engagement with key participants such as iwi/Māori communities and non-government organizations. According to the report, a successful strategy is that which is built politically from the bottom-up and technically from the top-down. The dissertation discusses a way to allow all the stakeholders to participate in a negotiation to plan and design a future infrastructure. Such negation between different stakeholders can bring critical support on changing land-use plan or instigate complementary investment for local government in other infrastructure or development. Again, as a means of reconciling RMA (Mfe.govt.nz, 2019b) frustration, the employed VE design approach can compete with the international urban design practices that already have adopted flexible,

forward-looking and market-driven design systems to foster economic growth and value.

9.6   Contribution to Knowledge

This dissertation extends the practice of continuous laypeople collaboration and participation in 3D spatial design in a participatory urban design approach. It has done this by developing the immersive design tool and the engagement procedure. The contribution of the research lies in two different areas: the affording laypeople in design communication and the generation of 3D artefacts for urban design collaboration.

9.6.1 Affording Laypeople in Design Communication

Designing with VE offers new opportunities for the laypeople to engage in the urban design discussion. The affordance of perceptual awareness of the instrument encourages laypeople to engage in design communication and collaboration. The employed media acts as an extension of perception, which allows pre-conceived design ideas to be visualised fully. The collaboration activities happen in various stages of design through verbal communication, presence, and co-presence with the generation of 3D artefacts. The value of affording non-experts contributes to an authentic urban design collaboration that generates bottom-up information for stakeholders.

In terms of design decision making in particular to visual perception, the VE experiment setup provides effective transmission of information, which enables the laypeople to process the information in a conveyance way. The experiment setup allows them to deal with the design complexity, which is superior to their design skills. The affordance of technology offers certain types of design interaction that is active and interpretative. The quality of the technological affordance allows the designers to take design action according to the perceived quality of the attributes of the generated 3D artefacts. Those artefacts mediate next design action. The designers conceptualize the attributes of the artefacts as urban forms with conversation and shared representation.

Besides, like civic engagement, the conceptual models deal with the issues of rational ignorance, which help the laypeople to come into consensus in a short period. The experimental setup enables the citizen to immerse and involve themselves in design situations to the point of "being there," bringing the sense of the experience of walking in the neighbourhood.

In other words, the research demonstrates that the distance between the laypeople's collective imagination and its representation, visual communication, and realisation can be reduced by using a low threshold-based immersive instrument in the early design stages. It empowers laypeople to express, explore, and convey their imaginations, and to engage actively in urban design. Non-experts' urban design engagement in a VE is still emerging, and hitherto no particular strategy has developed on how VE can enhance the act of local community collaboration and participation in urban design. The shortcoming of conventional design communication in participatory urban design methods needs to be further addressed and investigated.

9.6.2 3D Urban Design Collaboration

The finding of the research moves us closer to a better understanding of how to integrate an easy VE facilitated generation of 3D artefacts for laypeople's spontaneous urban design collaboration. The thesis demonstrates that integrating suitable VE minimises the distance between the non-experts' collective design imagination and its representation during the initial stage of urban design. Most tools in VE are used for design consultation through presentation or simulation. By analysis of design conversation and representations, my research has demonstrated that laypeople's collaborative conception, perception, and understanding of 3D artefacts within VE contributes to the quality, understanding, and designing of urban space and form. Moreover, the easy nature of design creation, communication, and collaboration offers an opportunity for experts and non-experts to collaborate in the early stage of urban design. Therefore, it re-establishes a new direction to include stakeholders in the design process where the intuitive design communication empowers non-experts to participate in a spatial discussion

on designing future neighbourhoods. In a broader context, the research undertaken in the thesis has not only moved the VE from architecture to participatory urban design, but also from the expert realm to non-expert realm in a novel and materially different way.

The act of design interaction produces a body of knowledge, which through protocol analysis on verbal conversation shows how non-experts engage in the urban design process. The judgement is based on the perception of the spatial quality of the produced design options. A coding scheme was developed to analyse the verbal conversation that happened in the virtual design engagement. The results show that participants created urban forms through a shared experience. It suggests that the employed VE assisted generation of 3D artefacts in urban design engagement can be explored with a varied mixture of stakeholders, due to its easy nature of design communication and participation. In the end, the experts are getting bottom-up design ideas on urban forms which can be considered for further development.

Helfand (2001) states that the industrial age was merely a passing phase in which the quality of human life would be challenged to further the prowess of technology. The current nature of the technological interfaces enables anybody involved in the design process to directly affect a project's shapes, spaces, or surfaces. Supporting those speculations, the research shows how advanced technology can be applied in the collaborative design decision making process with local people's participation towards a meaningful outcome for future urban development. The findings show that the power of media technology is the externalised limb of mental function, which has been escalated through arguments by McLuhan and Lapham (1994). Subsequently, the contribution of the research is explored in the theoretical realm where media is no longer considered to produce information but to contribute through interaction.

Chapter 10   Limitations, Future Research, Critical Reflection and Conclusion

This chapter acknowledges the limitations of the research and then proceeds to the conclusion after projecting on future research.

10.1 Limitations

The research has limitations in terms of design representation, design participation and technical limitations of the engagement and the instrument. Despite this, the study has shown positive results to validate the research questions.

10.1.1 Design Representation

Greg Lynn states that *"there is a language of design that the computer brings with it, and mainly, you do what the software does well"* (Hemmerling, 2018, p. 4). This proponent is undoubtedly true to some extent for the research. Participants only could generate 3D artefacts in perspective views. The VR instrument could not generate irregular shapes. Subsequently, the design outcomes are dependent on the ability of the instrument. The design proposals

have a basic appearance, akin to a massing model, which does not match a high level of fidelity of the environment in which the designs are placed.

10.1.2 Design Participation

Designer A and *Designer B* cannot directly see each other. *Designer A* stands in avatar mode and designs independently. *Designer B* is as well as an independent viewer who interacts verbally and emotionally, which reduces the limitation. Also, the design participation is reduced to its instrumental value (Lyotard, 1984) as the performativity of the participants cannot go beyond the discourse of fixed rules offered by the design task and the instrument. It reduces the open-ended discussion, which requires more time to reach an agreement. In that sense, the design engagement helps to arrive at an agreement on conflicted and interrelated issues relevant to urban design in a reductionist manner. That means it is missing some interrelated urban complex aspects which are essential to forming an inclusive urban design.

Besides, there is another variable which may affect the number of participants, such as the fact that the initial design consultation was closely associated with WCC, whereas, the IVE experiment was known to be a part of PhD research. Involvement of WCC in the experiment may increase the number of participants. Also, the participants were potentially more committed to their exercise as quite a high proportion of them in the experiment already had some skill with VE.

10.1.3 Technical

One of the technical limitations of this experiment is that the design collaboration happened in two different VR mediums, which has two different perceptual understanding. Due to these differences, it is evident that the designers have a different understanding of spatial awareness and different perception of size and shape of the 3D urban models.

In the research, technology cannot solve all the rational problems of diversified citizen participation. However, a citizen who maybe not interested in the participatory design process can be interested in participating in such a virtual design platform or vice versa. Additionally, the potential of such

innovative technology is bringing creative ideas and original views of citizens to design their neighbourhoods. However, this voice cannot answer all the aspects of complex problems.

Another limitation of the study is that the VE instruments did not include any audio or any other sensory features. The 3D representations are not-photorealistic rendered. It is however stated that 3D immersive virtual environments potentially created a more natural environment for the brain in qualitative building simulation, as compared to conventional 2D representations (Hermund et al., 2017).

To provide sufficient knowledge and hands-on experience with software tools, depending on the participants' prior knowledge, it takes time to become familiarised with the system. The headsets, controllers and the manoeuvring operations were new to the designers. During the design process, interruptions occurred several times due to the unfamiliarity of the VR instrument.

I have mentioned earlier in Chapter 4.1.1 that discrepancy between latency and sensorimotor can hinder the communication. During the engagement, most often, the continuity of the designs are interrupted frequently due to operational discrepancies between software and designers. It caused breaks in the flow of design communications.

10.2 Future Research

The thesis focuses on design collaboration within VE, so future research would be to test the concept for different case studies either in neighbourhood design or infrastructure design. The future research also would be to ensure the same perceptual affordance for all the design collaborators. The employed VE setup also has the possibility to collaborate with multiple stakeholders via online from remote locations, which I also want to explore as next endeavour. The ever-evolving CAAD technologies can make it possible to have more interaction within IVE by moving the act of design away from its abstract and isolated realm by blending with reality. Incorporating Augmented Reality (AR) setting can explore how virtual interaction can be made by being present

physically in the real site. A possible future direction of this research can investigate cognitive strategies in design, such as EEG or functional Magnetic Resonance Imaging (fMRI). The brain scanning attempts will verify the data of current experimental study of design activities by direct measurement of brain activities. Also, an addition of sensory immersion will be more effective to make the collaboration more natural. The overall design discussion can be happened being physically walking in the real site or virtually walking in the 3D scanned model of the investigation site. Emerging technologies like drone scanning can bring the site with more authentic information in an indoor design collaboration set up. Bringing advanced technology to capture the real urban context make the design experience more informed and eventually can able to capture the complexity of intangible cultural heritage and the related social, political and economic issues surrounding the sites (Kalay et al., 2007). Such digital media utilizes much more than re-creation and re-presentation of physical entities. In summary, an extension of my research to the realm of urban design management can offer a new way of interpreting the collective design inclusive design decision making in a 1:1 scale informed VE. The integration of VE design thinking into strategic management as a cross-disciplinary collaboration will help the relevant stakeholders to form design decisions in a time and cost-effective way.

10.3 Critical Reflection

The research journey is full of a different set of tasks. The onset of the journey starts with understanding the concept of 3D design representation in the urban design process. It motivates me to point the gap in the existing literature on the techniques of the urban design process in terms of laypeople's perceptual understanding in design communication.

One of the aspects of the NSC-BBHTC challenge is to involve stakeholders in a co-creative and innovative way of shaping future neighbourhood with effective deployment of digital media. In that sense, the research is informing a new understanding of how a VE can act as a driver for design initiating and sharing in developing an urban scenario. The alignment with a real-case encourages me to develop the VR instrument and

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the experiment setup for design collaboration between stakeholders and citizen. The VE setup leverages the designers to generate urban design alternatives for an empty lot of Karori. Through the research journey, I learn that with sufficient technological and perceptual affordance of design instrument can allow laypeople to be an active member in the early stage of design ideation and generation of an urban design process.

It starts with understanding the basic concept of 3D representation in the design ideation stage. Literature like Luck (2007) mentions that the physical 3D artefacts at the early stages of design are appropriate for urban design discussion, as it develops users' understanding of the design. The design discussion builds the user's confidence in the appearance of the design and prompts ideas to modify the design, which is found through the design experiment. The design interpretation as a part of design process realises through conversation and action. The designers in VE experiment are progressed in design discourse through design actions. Every design action to generate 3D artefacts initiate a new understanding of the shared design. The designers generate mental images of real-world problem reflected from perception. It gives me the understanding that the cognitive phenomenon of perception provides meaning to the 3D artefacts, which leverages laypeople to generate, interact with and share design.

I also look at the literature on design instruments using in urban design processes. The conventional urban design process provides specific visual consequences with the types of representation instruments based on pen-pencil, paper, photographs and physical models. Initially, Al-Kodmany (2001), Forester (1988), Friedman (1973), Steino et al. (2013), Bannon et al. (2018) and Ehn (2017) works help me to frame the gap in communication tools in the participatory design process. Later, through precedent literature, I find researchers are exploring and suggesting a different tech-driven solution to reduce the gap. Research like Petzold et al. (2014), Seifert et al. (2016), Drettakis et al. (2007), Seichter (2007), Lo et al. (2019), de Klerk et al. (2019), Beattie et al. (2017), von Heland et al. (2015) and Markopoulou et al. (2018) show the possible integration of VE in urban design process. But

they are focusing more on techniques, not in the realm of 1:1 scale (life-size) perceptual awareness and intuitive 3D design generation.

Developing the design task for laypeople is another challenge for this research. The design task aligns with the interest of the residents of Karori. According to the concept of the participatory urban design process, the participants from a neighbourhood are involved in a design process to deal with a real-life problem with specific needs, problems and expectations which are different from other neighbourhoods (Pissourios, 2014). In that sense, framing the design task to incorporate the Karori residents is a crucial step in this research. The report of the WCC on the charrettes conducted in the neighbourhood helps me to know the primary interests of the residents. I consider the preliminary survey outcome to frame the design task. The result of the survey indicates most of the Karori residents want to design by themselves in visualising their City Centre. So the design task to generate a new urban form around City Centre gains accountability from Karori residents.

Having a background from architecture, I am accustom of generating 3D artefacts in VE as intuitive manners with the constant reflection of own design actions. Most cases, we habituate ourselves with the technological affordance of the design tools. But for first-time users, it is difficult to orient them in the design process to generate a meaningful design. The literature like Schnabel (2011), Schön (1992), Brown (2003), Cross (1972) and Luck (2007) together help me to conceptualise the phenomenon of 3D design action, reflection and representation in VE, which supports me to speculate the possible design interaction by laypeople before the VE experiment.

The perceptual understanding of the 3D artefacts varies with the affordance of the VE instruments. I realise that by exploring software like 'Grasshopper 3D', 'Unity 3D', 'Fuzor', 'VRSketch' and 'Hyve 3D'. The technological and perceptual affordances are different for each system. The perceptual understanding of the same 3D model for Karori varies with the instruments. Also, the selection of the instrument for an experiment depends on the nature of the design task. Initially, I develop 'Grasshopper 3D' based

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parametric interface link with 'Unity 3D' to generate 3D artefacts with numerical input of density, building height, width, plot division and construction cost. The data streaming between two software is not compatible enough to produce a standalone interface for laypeople to participate in an effective design discussion. Also, the rendering quality is not detailed enough to conceive a perceptual understanding of the Karori neighbourhood. Both 'VRSketch' and 'Hyve 3D' are required time for first-time users to habituate with the technique of design generation in the systems. Besides, 'Hyve 3D' cannot generate 3D artefacts as a design element. The perceptual understanding of the Karori site is well rendered in 'Fuzor' but its lack of capability to generate 3D artefacts in an intuitive manner, which does not encourage me to use in design experiment. In the end, I pick the 'Unity 3D' based VR instrument 'SketchPad' developed by Innes et al. (2017) which supports the design task in a flexible manner.

The research shows the capacity to inform my role as a facilitator to leverage non-experts design participation. To facilitate VE design experiment, the design task aligns with the capability of design generation of the instrument. The setup of the design experiment is one of the crucial factors in this research, where one designer immerses in HMD and other designers monitor the output in the 80-inch display screen. From the experiment, I learn that the easy nature of 3D generation and visual communication along with verbal exchange make the design discussion effective. The designers involve naturally in design discussion along with the design action and 3D artefacts. To analyse that I adapt methods of protocol analysis which is a way to investigate conversation as a shared form of design behaviour. Developing the coding for protocol analysis reflects the types of the conversation happened during design sessions. The results of the protocol analysis show that the sessions end with maximum conversation in design communication.

In summary, the research experience is a lifetime opportunity for me to discover my strength in aligning different disciplinary tasks towards an applicable stage. The research not only offering a novel method to involve laypeople in VE design generation but also giving them a chance to take part actively in imagining their urban design ideas.

10.4 Conclusion

The dissertation shows that Virtual Environment (VE) facilitates design communication for laypeople in an urban design process. It presents a VE assisted design methodology to involve laypeople to take part actively in the early stage of design ideation and generation. The inherent characteristic and affordance of the VE instrument reduced the divergence between the design ideas and their perceptual understandings. The immersive VE experiment setup affords laypeople in a communication process, where they design together and make decisions on future urban form. Laypeople participate as designers and generate meaningful outcome with 3D artefacts, which can be understood by experts. Designers take design decision on 3D artefacts in the virtual environment and seek feedback from the fellow designers. They participate as a team. The feeling of affiliation with each other activities in the experiment setup, let the laypeople produce authentic design discussion. In the process, the experts come later, where the laypeople can generate understandable urban form without the help of experts.

The current urban design practices comprise complex activities that mostly too difficult for citizens to understand or take part collaboratively. The study involves citizens from a community to design their neighbourhood. The VE as a mean of communication and participation allows citizens to take part actively in the process to express, explore, and convey their imagination easily. The perceptual and technological affordance of the VE allows them to get into design discussion with design actions associated with the generation of 3D artefacts and verbal exchange. The spontaneous exchange of visual information in a VE along with verbal communication helps them to produce meaningful urban design outcomes. The employed VE technology allows citizens to afford perceptual understandings of the 3D artefacts as meaningful urban form, which exerts no threshold for contacting emotionally as social units.

The thesis has examined in the context of New Zealand's National Science Challenge 'Building Better Homes, Towns and Cities' driver of change that contributes to the shaping of places, development and design of

future neighbourhoods. It presents a method to develop a design task relevant to a suburban redevelopment case in New Zealand. The process shows the possibility to facilitate 3D design communication on urban form among multiple stakeholders. Projects those employing this VE instrument and the experiment setup can shape and develop New Zealand's future neighbourhood through active participation of people in 3D design enquiries.

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2. S. Chowdhury and M. A. Schnabel (2019) Virtual Medium of Design Participation: Empowering Laypeople in Urban Design, in Dr Avolika Agrawal (ed.), *Revisiting the Role of Architecture for 'Surviving' Development*, the 53rd International Conference of the Architectural Science Association, IIT Roorkee University, Roorkee, India, 10 pages.

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2. S. Chowdhury, M. A. Schnabel and R. Kiddle. Virtual Environments as Medium for Laypersons' Communication and Participation in Urban Design. Poster Presented at PhD Symposium; 2019, 24 October, Victoria University of Wellington, New Zealand.

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Appendix A

Preliminary Survey Questions

Co-design Process in Neighbourhood Design Survey

Karori Resident: ❑ Yes ❑No   3D skilled: ❑   Yes   ❑   No

Your reaction towards the design engagement:

1) Can you find the given information enough to understand the spatial arrangement?

❑ Absolutely! ❑ It is OK ❑ Neutral ❑ Not Really ❑ Not at all

2) Can you visualise the proposed design ideas?

❑ Absolutely! ❑ It is OK ❑ Neutral ❑ Not Really ❑ Not at all

3) Can you visualise the proposed design ideas in 1:1 scale?

❑ Very much! ❑ It is OK ❑ Neutral ❑ Not Really ❑ Not at all

4) Is the visual information enough to make your own fully informed decision?

❑ Absolutely! ❑ It is OK ❑ Neutral ❑ Not Really ❑ Not at all

5) What should be changed/improved/added to the understanding?

_____

6) How easy was it to collaborate with stakeholders, i.e. designers/peers /fellow community people?

❑ Very easy! ❑ It is OK ❑ Neutral ❑ Not Really ❑ Not at all

7) Do you prefer the given design solution with choices or would you prefer to design your own design?

❑ set solution   ❑ own design ❑ a mixture of both ❑ no preference

Feedback Survey Questions

Virtual Design Process in Neighbourhood Design Survey

Karori Resident: ❏ Yes ❏No   3D skilled: ❏   Yes   ❏   No

Your reaction towards the design engagement:

1) Can you find the given information enough to understand the spatial arrangement?

❏ Absolutely!   ❏ It is OK   ❏ Neutral   ❏ Not Really   ❏ Not at all

2) Do you think abstract produced models help you to visualise your initial design concepts?

❏ Absolutely!   ❏ It is OK   ❏ Neutral   ❏ Not Really   ❏ Not at all

3) Do you think contextual site information guiding you to take your design decision?

❏ Very much!   ❏ It is OK   ❏ Neutral   ❏ Not Really   ❏ Not at all

4) Is the visual information enough to make your own fully informed decision?

❏ Absolutely!   ❏ It is OK   ❏ Neutral   ❏ Not Really   ❏ Not at all

5) What should be changed/improved/added to the understanding?

_____

6) How easy was it to collaborate with stakeholders, i.e. designers/peers /fellow community people?

❏ Absolutely!   ❏ It is OK   ❏ Neutral   ❏ Not Really   ❏ Not at all

7) Do you prefer the given design solution with choices or would you prefer to design your own design?

❏ set solution   ❏ own design ❏ a mixture of both ❏ no preference

Evaluation Questions

<u>Virtual Neighbourhood Design Evaluation</u>

Karori Resident: ❑ Yes ❑No   Years   of   Experiences:

Your reaction towards the design engagement:

1) Can you find the given information enough to understand the spatial arrangement?
   ❑ Absolutely!   ❑ It is OK   ❑ Neutral   ❑ Not Really   ❑ Not at all

2) Do you think abstract produced models help you to evaluate the design concepts?
   ❑ Absolutely!   ❑ It is OK   ❑ Neutral   ❑ Not Really   ❑ Not at all

3) Do you think contextual site information guiding you to take your design decision?
   ❑ Very much!   ❑ It is OK   ❑ Neutral   ❑ Not Really   ❑ Not at all

4) Rating for different models (every attributes out of 5 , 1= Not at all, 2=Not really, 3= Neutral, 4 = It is Ok, 5 = Very much)

   Design 1: Functionality   ; Aesthetics   ; Experiential   ; Overall

   Design 2: Functionality   ; Aesthetics   ; Experiential   ; Overall

   Design 3: Functionality   ; Aesthetics   ; Experiential   ; Overall

   Design 4: Functionality   ; Aesthetics   ; Experiential   ; Overall

   Design 5: Functionality   ; Aesthetics   ; Experiential   ; Overall

   Design 6: Functionality   ; Aesthetics   ; Experiential   ; Overall

   Design 7: Functionality   ; Aesthetics   ; Experiential   ; Overall

   Design 8: Functionality   ; Aesthetics   ; Experiential   ; Overall

Appendix B

Transcription and Coding

Group Three: Option 4

Source File: Rec-B_1.1_0633.wav (00h:18m:19s)

Beginning of design session – Part 1

Designer A: [NRT] 08:31 of me talking to Henry about laser eye surgery and motorbikes.

Designer A: [05:10]   [NRT]   [laughs] Ooo can you see the edge now?

Designer B: [05:14]   [VWS]   We've got the beginnings of the resemblance of one

Designer A: [ACC]   definitely

Designer B: [05:18]   [NRT]   so do you guys want to start?

Designer A: [05:20]   [IDE]   alright I'll chuck some walls down [INT] and you tell me if [INT] you think that would be better else where

Designer A: [05:23]   [ACC]   yeah

Designer B: [05:24]   [NRT]   thanks guys!

Designer A: [05:26]   [NRT]   oh, you want to join? — you can join!

Designer B: [05:28]   [NRT]   oh, I still have to pack up, I'm still working but yeah

Designer A: [05:32]   [INTS]   is it, is it cleaned up or do we just reset it?

Designer B: [05:35]   [INTS]   we reset it, yeah

Designer A: [05:37]   [JOK]   as nice at those pyramids where [laughter] probably not part of our plan

          [] [inaudible]

Designer A: [05:47]   [JOK, NRT]   I love seeing people have their first VR experience, I usually like to um give them a little bit of getting used to it, make sure they're not getting a headache or something and then drop them in the deep end with some like roller-coaster

          [05:57] [JOK]   [laughter]

Designer A: [05:59]   [JOK]   and they're like wwwwwwhhhhhhhaaaaaaaa

Designer B: [06:01]   [JOK]   yeah, they're like woah — grabbing onto shit or the one when they're reaching out trying to touch things, I still do that sometimes like fuckin' that's when you know it's working.

Designer A: [06:08]   [NRT]   I'd love to get a headset one day but I just do not have the space at home for it aye [INT] like you'd want a decent sized space for it

Designer B: [06:12]   [NRT]   yeah yeah

Designer A: [06:15]   [NRT]   and these are beginning to look old school now [INT] cause they're like wired-in …

Designer B: [06:18]   [NRT]   yeah

Designer A: [06:19]   [NRT]   ah yes that's my hand but I can do the controller

              [06:22]   [NRT]   oh, yes one second it's coming up

              [06:25]   [PAU]   [background chatter – inaudible]

              [06:29]   [NRT]   cool, cool, alrighty

Designer B: [06:36]   [NRT]   just one minute, yep

Designer A: [06:40]   [JOK]   nice Jeep or whatever it is

Designer B: [06:42]   [JOK]   [laughter]

Designer B: [06:43]   [NRTN]   Designer A do you want to take a seat or … hang over here

Designer A: [06:45]   [NRT]   Mmm…

       []   [inaudible]

Designer A: [06:49]   [VSS]   Okay, so, the driveway, is there a driveway? Is there an entrance?

Designer B: [CLAS]   yeah, is there a specific place that you might have a driveway?

Designer A: [VSS]   Is there an existing one on the street? On this model there isn't but we'll make sure

Designer B: [VSS]   Um, I think — what was it, from Campbell Street. I think this was an access way

Designer A: [07:18]   [IDE]   okay, so first of all, um over this way, do we want the wall to be on this side of the fence or on that side? Or are we just getting rid of this fence or …

Designer B: [07:28]   [DEV] Um… I'd get rid of the fence not that you can

Designer A: [07:31]   [INT]   okay, okay, so we'll pretend the fence is gone

Designer B: [07:36]   [VSP]   Well I probably can get rid of the fence but it's like currently in existence so…

Designer A: [07:40]   [ACC]   Yeah

Designer A: [07:44]   [VGT]   Okay, so… wait, here? A wall here maybe? like here or like here maybe?

Designer B: [DEV]   So I reckon like, move to your left. No I reckon have an open sort of wall or maybe a sliding door open up towards the road

Designer A: [ACC]   Okay

Designer B: [INT]   and have a wall right down the side yeah right along there wait I reckon yeah n't there on this model there isn't

Designer A: [CLAS]   this side here?

                [HAN]   you can see where I'm pointing right?

Designer B: [VWS]   yeah yeah

Designer B: so …

Designer A: [VWS]   it's like one big long wall where you are facing towards Campbell Street

Designer A: [08:16]   wait hang on

Designer A: [VTXT]   speaking of materials, is that the skins

Designer B: [08:21]   [VTXT]   that those skins

Designer A: okay, sweet

Designer B: [VTL]   if you want to get a shape go to the add section and shapes will come up

Designer A: [08:41]   okay so… add

Designer B: [08:50]   [INS]   I reckon just start with a cube and stretch it out

Designer B: [08:56]   [VTL]   yeah, I powerful function is um, once you've made the cube just use the push and pull and you just go the face you want to extend just drag that. It seems like the best [INT]

Designer A: ah, yeah. Yeah

Designer A: [VSZ]   How tall do we want it, like 3m?

Designer B: [VSZ]   Nah, I reckon taller, maybe try for 6m

Designer A: [VSZ]   6? [laughs]

Designer B: [VSZ]   ah, why not? May-maybe 5, 5. I don't know, I'm just making shit up

Designer A: we-we can play around

Designer B: [INS]   yeah, yeah and just yeah pull it all the way down to the other end

Designer A: [VTL]   which is move? No, pull [INT] oh push pull

Designer A: [VTL]   is it scale?

Designer A: oh yeah

        [09:35] [HAN]   Designer B did you see how-um- the face of it …

Designer B: yeah, lights up

Designer A: [09:40]   [TKQ]   how far?

Designer B: [INS]   all the way down towards the trees

Designer A: [09:43]   [VTL]   where's the measurement – it doesn't give one with *pull…* okay

        [09:47] [VWS]   alright, well we've got some branches

Designer B: [09:51]   ah, that's fine

Designer A: [09:52]   [INS]   so maybe pull it back a bit?

Designer B: [09:55]   [INS]   nah nah take it all the way down, I reckon

Designer A: [09:57]   [VSM]   no I mean, pull it closer to where I'm standing

            [09:59]   []   oh, yeah-yeah

Designer B: [10:04]   [AAR]   yeah, it's going to be this tall it's going to need to [INT] but we don't need to worry about that right this second but…

Designer A: [10:14]   [NRT]   Um yeah, you have to have it on an angle otherwise. I know because I fucking renovated my property in Otaki and had a bunch of that bullshit with it.

Designer B: [NRT]   So the face you have selected lights up, it's that how it …

Designer A: [NRT]   Yeah

            [10:30]   So that's

Designer B: [10:33]   [INS, VSS]   Yeah I reckon take it all the way down cause then like you can have specific areas inside it, you can break it up.

Designer A: [VSS]   This outdoor area over here probably wants to stay, but that's doing [INT]

Designer B: [ACC]   That's true

Designer A: I dunno, it doesn't have to but like of all the — of all- there's not much here

Designer B: [ACC]   Yeah nah leave that there I reckon

Designer A: So And then

            [CLAS]   Roller door — On this side, or do we want something on this corner maybe to be window or something

Designer B: [DEV]   Can you make it a door, That's alright, no worries

Designer A: [VTL]   If I-if I put—if I put a voxel – wait how do I do the select again

Designer B: [11:23]   [IDE]   Yeah, just do an outline

Designer A: [CLAS]   So I could do like this

Designer B: [CLAS]   Oh yeah, to show where the window could be

Designer A: [DEV]   Well I mean then it has a hole in it so it's a bit more like a window than a solid cube. Maybe I'll build it a bit more closer to me – so like that

Designer B: [DEV]   Yep, so squeeze it really close together

Designer A: [VTL]   Hmm… how do it do it laterally? Do I need to have that face there or something

                     Yeah

                     So — um I wanna go. Mmm… I'm going to have to

Designer B: [VTL]   [laughs] so if you can stretch it all the way wall

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Designer A: [NRT]   Oh, I'm going to… it's not like rushed thing. Um

Designer B: [13:26]   [NRT]   this is fun

Designer A: yeah

               [VTL]   Yeah, alright, so. Can I copy an object?

                          Yes, and it also works like it's going to copy and slide it in the
direction

Designer B: [VTL]   Ah, okay. So there's two on top of each other now?

                          Ah, yeah

                           Oh, is it still coping?

                          I think you copied it twice

Designer A: [VTL]   Okay…

                           It's stuck on that face

           [VWS]   Which side go I want to press on it to rotate it this way

Designer B: [VTL]   I think you want to grab it on the edge

                          You   don't   have   to   do   it   from   the   to   do   ya?

Designer A: [VTL]   no – I'm not sure how to do that – is there a separate control

                          Ah, that copies on an angle

           [IDE]   Okay hang on, Lets just get rid of these and start again. Wait I've
rotated this one now

Designer B: [CLAS]   Have you?

Designer A: [CLA]   Well look

Designer B: [VWS]   Oh no you've just sticking out from the wall just slighty that's all

Designer A: [NRT]   Oh yeah

           [15:29] [CLAS] Oh did I get it?

Designer B: [ACC]   I think so

Designer A: [NRT]   Okay

                          Nah that's alright, its not going to be flawless or anything

           [AAR]   It's just the general idea of shape style and function

Designer A: [VWS]   Okay, so. You can sort of see out there a bit I think maybe a bit more window on that corner

Designer B: [EVA]   Yeah, yeah I think that's good to start with cause it's like I reckon it could be either rolling or folding doors

Designer A: [VWS]   But I would kind of would like to be able to see out and people to see probably, so I'm going to move this in

Designer B: [ACC]   Yep

        [17:08] [JOK]   [laughs] ah it's another one. How many did you copy?

Designer A: [NRT]   I must have like quadrupa tapped it or something

Designer B: [VTL]   Can you feel it snap onto the end?

                               Yep, that was good!

        [CLAS]   Um why's it pink now?

Designer A: [INTS]   How do I unselect it?

Designer B: [VTL]   Nah just click somewhere maybe, with the trigger?

Designer A: [17:39]   [INTS]   Well I've been __ other objects and it's still…

Designer B: [17:42]   [VWS] that doesn't matter. Um, ah, that's a bit more like it so from the street I can see in… yeah that's pretty good. We might want to fit it that way but we're sweet fow now

Designer A: Yeah

                [INTS]   Ah, [laughs] shit, once again

                [NRT]   Oh who who, is someone here?

Designer B: [NRT]   No no

        [18:22] [NRT]   No ones here

Designer A: [18:23]   [NRT]   No one's here! Just me

Designer B: [JOK]   You're I the matrix now bro

Designer A: [18:29]   [TKQ]   Okay, um what's next, more window on this side? It's going to be roller doors aye?

        [AAR]   Yeah, I would leave it at the moment and put in the other wall

Designer B: [CLAS]   Okay, the real wall?

Designer A: [CLA]   Yeah, yeah

[CLAS] About here or further back?

Designer B: [18:43]   [IDE]   I reckon keep a gap there so you could have if they wanted to have maybe even a covered garden ?

Designer A: [ACC]   Yeah! Like an outdoor sheltered area

Designer B: [18:53]   [ACC]   Yeah,

            [CLA]   Sort of – from the - start them all at the same location – ah same point but pushed further back towards the back of the property. Does that make sense?

Designer A: [VSM]   It's like from where the wall is but go - say imagine walking back further.

            [CLAS] So what am I putting down? A wall is going to start here-ish or something?

Designer B   [ACC]   Ah, yeah there abouts or something

Designer A: [CLAS]   So from here along?

Designer B: [ACC]   Yep

Designer A: [INTS]   Am I getting twisted up I can't tell [laughs]

Designer B: [ACC]   Nah, nah you're right

Designer A: [NRT]   Okay, sweet, ahhhh [laughs]

Designer B: [NRT]   It's alright we got you covered [laughs]

                  [REJ]   I reckon nah--nah more of a gap

Designer A: [ACC]   Ah right

Designer B: [IDE]   So like it can be a courtyard or something

Designer A: [CLAS]   Like here?

Designer B: [ACC]   Yeah

Designer A: [VSS]   How far is this going, quite far?

Designer B: [ACC]   Yeah

Designer A: [VWS]   It's not level, for one thing

                  [VWS]   Ah the ground isn't level

Designer B: [VTL]   Yeah I know

Designer A: [VTL]   That's alright

Designer A: [NRT]   But we're not going to have to build the bloody thing

Designer B: [JOK]   No [laughs] they can sort it out

Designer A: [NRT]   Um,

Designer B: [20:26] [INS]   I reckon you can have an open space in the back there that's quite sheltered

Designer A: [CLAS] Behind this wall?

Designer B: [INS]   Like just in that area there where the gap is between the two walls

Designer A: [CLAS] Have we got some objects like chairs or something or should we just place things that represent them

Designer B: [ACC]   Yeah

Designer A: [JOK]   Shall I do some of that – lets just focus on the fuckin' building

Designer B: [ACC]   Yeah yeah – I spose it needs a roof aye [laughs]

Designer A: [DEV]   Yeah um, we should probably get an idea of the foundation level first

Designer B: [21:00] [INS]   That's true – chuck in a floor maybe

                [CLAS]   So, make a flat ground between here and there

Designer A: [ACC]   Yeah

                [inaudible background voices]

                [VWS]   Ah yeah I can just make it taller for now and then flatten it when I – cause then it's easier to grab the edge

Designer B: [ACC]   That's true

        [22:21] [IDE]   Hey I reckon it's all good it you want to delete that fence just to get it out of the way

Designer A: [VWS]   Okay, I'll move this then before I delete that

                [JOK]   Can I get one of these remotes for real life, I promise I'll use it for good!

                [PAU]

Designer B: [VWS]   So, that's how – needs to be level at this end.

Designer A: [CLA]   So, that's - what's that distance over here? What's that distance over there – what's that height there? Not heaps, so do we want steps and a ramp or something? [HAN]

Designer B: [ACC]   Yeah

Designer A: [23:38]   [CLAS]   Or do we want that level to be levelled down to the level of this side?

Designer B: [CLA]   Ah, I mean that's the thing, I could just be like if they went with that design they could always just do that themselves

Designer A: [ACC]   Yeah

Designer B: [ACC]   They could just decide at the time, but um. I'd worry more about the roof and like the space within

Designer A: [23:55]   [CLAS]   Yup, okay so, is this a good amount of floor space, do we want some more?

Designer B: [ACC]   Yeah, I reckon. We can start off with that we can always stretch it out.

Designer A: [IDE]   Like it's sort of a gallery area right?

Designer B: [ACC]   Yeah that's what I was thinking

Designer A: [JOK]   Alright, so If I take my — my window box and reshape it with my phenomenal cosmic powers

              [laughter]

     [24:37]   [VWS]   This one doesn't just have to be a window it can be a roller thing or whatever.

              [VSP]   French door type of thing

Designer B: [ACC]   Well, I do really like the option of it being open but it's going to need to be able to be closed as well so that's pretty much [INT]

Designer A: [VWS]   so that's – I know massive bi-fold doors are possible so like they will close like an accordion

              [laughter]

     [VWS]   I'll just move it down that's easier… oh

     [25:37]   [INTS]   So I always appear in the same place when I go underground is that what's happening – down the road. Can you make your spawn point like closer

[laughter] yeah

Designer A: [NRT] so I usually lock this up but you guys are able to lock it up aye?

Designer B: [25:52] [NRT] yeah, we've got the key

Designer A: [NRT] yeah sweet thanks, I got to get going 'cause my mate that works for me needs to get somewhere today but yeah [INT] thanks for letting me have a go.

Designer B: [NRT] sweet

Designer A: [VWS] I keep trying to make all these fucking the same height but I keep ending up in the floor

Designer B: [26:30] [INS] a possible suggestion is to like make one at the right height and then just copy paste them

Designer A: [INS] Yeah or just stretch one side

[VWS] I can snap them to the ceiling when the ceiling is one aye, maybe I should put a ceiling for now. Well I could just copy this piece.

Designer B: [INS] Yeah just do that

Designer A: [VTL] So when I'm copy it I'm also dragging yeah?

Designer B: [VTL] Yes

Designer A: [VTL] Is there and un-do button

Designer B: [VTL] No, we haven't figured that out yet

Designer A: [27:05] [VTL] Yeah there should be there should be - if you hold down the button then press another button while still holding it will cancel the action or something

Designer B: [VTL] Yeah, that'll be alright

Designer A: [INTS] Cause, this way it's like as soon as you pressed it – whoa glitchiness – [INT] collision detection

Designer B: [27:24] [VWS] that's two faces sitting on top of each other

Designer A: Yeah [laughs]

[INTS] Ah damn, see I just did that – what the fuck – ah I'm copying them no, no, I did that 3 times!

Designer B: [INTS] Damn you copy function, you're going to be the bane of my existence aren't you?!

[] [JOK] Make good use of the copies even though they can be created and destroyed at will without any actual resources being consumed

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[]   [laughter]

Designer A: [28:18] [VWS]   Well, we've got the beginning of something here, do you want to have a jump on for a bit Campbell [INT] before I sweat this thing up anymore

Designer B: [28:23] [ACC]   yeah – yeah

Designer A: [28:30] [VWS]   I'll pass the controller once you get in there aye

Designer B: [28:36] [VWS]   Alright, sweet, okay. What have we got?

Designer A: [VTL]   Bit different in 3D aye?

Designer B: [VTL]   Yeah it is, it's way different actually, um okay

Designer A: [VSM]   Especially moving around it

Designer B: [NRT]   Yep

Designer A: [28:58] [VTL]   definitely a really good tool to use. I'm not sure how of the people you'll get in here will be competent at using it but it's still cool.

                [VTL]   oops

[29:08] [VTL]   I mean, I'm—like probably have somehow what more of an idea of what I'm doing than the average but I'm still having a steep learning curve

        []   []   [laughs]

[29:30] [VTL]   really cool project to be doing. I hope you guys get some good stuff to show out of it like concept design or whatever. Cause then we'll start doing something more often

Designer A: [NRT]   What the hell did I do over there?

                [NRT]   We're going to try get – save all the designs and make a whole bunch of posters to put up in the library to show…

Designer B: [VTL]   yeah -- yeah uh, what function are you using?

Designer A: [29:58] [VTL]   Copy

        []   []   Yeah [laughs]

Designer B: [VTL]   That copy function aye

Designer A: [VTL]   It's fine I'll just copy and then move it

                [VTL]   How are you making it not appear when you let go of it? Cause that's exactly what I wanted to be able to do with that, but I didn't…

Designer B: [CLAS]   Um, what do you mean?

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Designer A: [VTL]   Like when you were dragging those copies that were disappearing when you were letting go of the thing

                [INTS]   I don't know, [laughs] it just stopped

                [VTL]   If I could do that on purpose that would be real handy. Ah there loads of objects on top of each other, that's a shame

Designer B: [VWS]   Ah there are two

                [VTL]   If you get the delete function and just click it at one time, careful not to delete the last one

Designer A: [VWS]   There we go

                [INTS]   The other one is probably under the ground. Just going, why's it not working – maybe if I press the button a few more time

                [VWS]   Go further dammit

Designer B: [31:04]   [VSM]   you have to move yourself to keep doing it.

                [VTL]   There's some aspects of this that would be slightly easier if you were just typing in the distances and banging out the objects that way – but you could probably do all that at the start and then just move then just move them around with the controller and stuff. That's' one thing that might be slightly easier. But um, you can definitely do it this way and once you got the hang of what work the best I'm sure it wouldn't be that slow

Designer A: [VWS]   Hmm…

Designer B: [31:34]   [VTL]   So this, this sort of teal box that appears – this like – don't walk past here otherwise you might walk into something

        [VTL]   The wireframe around you represents where you are in terms of
        on the carpet [INT] so if you start walking off you're going to pull that cord off your
        head and probably walk into us or into the wall or something

Designer A: Yeah

                        Ah yeah

Designer B: [VTL]   Just cause like when you get turned around in you have really no frame of reference for where you're standing in the real world so that's the wireframe is for.

Designer A: [VSS]   So we've got this massive space what are we doing with the rest of it [laughs]

Designer B: Um,

Designer A: [DEV]   Well at the moment it entirely massive space so a building that is nice to look at could be used for some exhibitions or whatever, that's definitely an improvement on an empty plot

Designer B: [ACC]   it is, yes. Okay, so

Designer A: [INS]   we definitely want to retain some nice outdoor space I reckon cause now the field is here we want something over there. And it doesn't have to be huge

[ClAS]   no…

Designer B: [ACC]   and – and I think you're right, having it on the same side at the walk way is definitely a good idea

[DEV]   and it's like, ah, this could almost be reversed so you could have this open area beside the walkway but at the same time you could have lots of garden around here … so

Designer A: [CLA]   on the street side?

[VWS]   Yeah, ah anyway let see what was I going to do … copy

Designer B: [INTS]   Whoa, what is this. Ah

Designer A: [INTS]   Whoa, why is this moving

Designer B: [INTS]   Maybe you grouped them I think

[33:41] [INTS]   Um, when you snapped them together they might have become the same object, possibly

Designer A: [VTL]   Right, interesting

Designer B: [VTL]   And – which means you can copy the whole thing – it is a useful thing

Designer A: [JOK]   Okay, apparently it's two stories now [laughs]

Designer B: [VTL]   With no access to the second story – just delete the second one if you – just be careful when you're deleting stuff cause like we – probably be quite easy to [INT]

Designer A: [VWS]   Ah….. and I just deleted the floor

Designer B: [VTL]   Ah just make a new one, or is there an undo?

Designer A: [VTL]   Wait I'll try a control z

[INS]   Hang on hang on hang on

| | [VTL] | Um, is there a control z? |

Designer B: [VTL] No no he's doing it on the computer, that's why I said don't press anything

Designer A: [VWS] I wonder if I can…

[INS] I think you have to …

[VWS] Ah I see, group function

Designer B: [VTL] Oh, you used the group function?

Designer A: [VWS] I didn't even – okay I'm getting

Designer B: [VTL] You might have clicked it instead of delete? Um, when selecting stuff I find rather than pointing at them it's actually easier to hold -- move your hand up and put the controller right in front of them [INT] like that [INT] then you're more likely to select the one you want. That's what I was doing.

Designer A: [VTL] Ah yep

[VTL] got ya!

Designer B: [VTL] Yep, nice!

Designer A: [VTL] So no undo? That's right, I can make a new floor

Designer B: [NRT] Yes, that'll be great

[VTL] Cause if you're just aiming it like using the angles it's actually quite easy to miss

Designer A: [NRT] Yep.

[PAU]

[VTL] okay, it's going to be …

[35:10] [VTL] yeah, that's the one. It's the handiest function in the toolkit

Designer B: [INT] is what?! oh, yeah!

Designer A: [VTL] the push/pull

Designer B: [VTL] You used it perfectly, like make a box and then…

[VTL] I've used similar sort of functions

[NRT] I mean I have but only in Maya [laughs] not in a virtual reality. Oop, you're alright?!

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Designer A: [INTS]   Okay, got a floor again.

                [NRT]   Am I super tangled am I?

Designer B: [NRT]   No, it's alright.

                [PAU]

Designer A: [36:30]   [VSS]   let's say there a step out there?

                [IDE]   Is that an visible wall?

                [VWS]   Is that a piece of glass?

Designer B: [VWS]   I don't know

                [ACC]   That's cool!

Designer A: [VWS]   There's nothing there to delete [INT] I'm selecting something

Designer B: [CLAS]   Is what a piece of glass?

Designer A: [VWS]   It's gone now

Designer B: [CLAS]   What is that!

Designer A: [VWS]   There it is!

                [EVA]   Is this stuff that other people have made and it's like remanence
of it, maybe?

Designer B: [VTXT]   It's an object has 100% transparent texture so you can
only see it when you hover over it

                [VTL]   When you're selecting it

Designer A: [VTXT]   [laughs] why is there an object with a transparent
texture? I have no idea

                [VTL]   There's nothing there though – there's nothing there to
delete, I dunno – weird

Designer B: [VTL]   Possibly left over from when you copied the entire
building and then deleted it

                [VTL]   … you've made a copy and it's sitting in the assets folder
somewhere

Designer A: [TKQ]   Yeah, what was I going to do? [mumbles]

                [PAU]

                [VWS]   Ah shit

[00:00] Background noise – chatter

Designer A: [00:06] [IDE] Um, we're going to start I think with just a plain old block

[NRT] What do you mean by list? Oh, that's right there's a list somewhere

Designer B: [00:21] [VTL]   Oh sorry it's gone now

[TKQ]   Just what type of buildings [sic]?

Designer A: [00:26] [IDE] Umm, I reckon we should build some-kind of sweet like adult playground [laughter]

Designer B:	[CLAS]	Mean.
Designer A:	[HAN]	What do you think?
Designer B:	[ACC]	Ah yeah, sounds like a good idea
Designer A: hang-out in	[IDE] (00:39)	[laughter] you know like, some shapes that people can
Designer B:	[INT]	Mean.
Designer B:	[ACC]	Yep.
Designer B:	[IDE]	Maybe with a café?
Designer A:	[VSP]	Yeah exactly, an outdoor café with shapes
Designer B:	[CLA]	Okay, go for it.
Designer A:	[DEV]	Okay, I'm going to try build the café.
Designer B:	[CLA]	Is that the café now?
Designer A:	[JOK]	[laughter] – "is that the café now" (01:00)
Designer B:	[CLA]	So, we're doing the café first.

Designer A: [IDE]   We do, ah… yeah, we need to make the dining area, you know   the   place,   the   big   place   where   they're   going   to   sell   it. I think here is good, maybe I'll just build a back wall to this thing. We'll have…oh no, maybe it's more, [laughter] maybe it's more like… maybe it's more… umm like a bar, and this is the bar. Can I do that Keegan? [laughter] Is that in the zoning rules?

[VGT]   So, what… so we've got like an area there… oh shit, is that the wall? (bumps controller against studio wall)

Designer B:	[ACC]	Yeah.
Designer A:	[VSM]	I want to go this way…
Designer B:	[HAN]	What are you building, Seth?

Designer A: [IDE]   I'm building a bar with an outdoor adult playground [laughter]

Designer B: [NRT]   That adult playground in Christchurch is pretty sweet…

Designer A: [DEV]   ...oh it's not an adult playground it's just a playground.

Designer A: [CLA, INTS]   Oh god, oh there we go, that's a better way of doing it, get this vantage point. So, what I'm trying to do – nah this could be a café – what I'm trying to do, ah no that's not what - I'm trying to - what how I wanted to do it. How do I cancel once you...

Designer B: [INTS]   …there we go it's out. It's gone

Designer B: [INS]   I guess just make the box and delete it, remember you pull up that menu (02:34)

Designer A: [NRT]   Ah yeah, umm…

Designer B: [HAN]   Okay, I'll let you go

Designer A: [IDE]   Maybe I'll go over here. I'm trying to build the same thing as I did on the other side again but I'm finding it difficult, yeah so it's like…

Designer B: [VTL]   Probably walk forward a bit and then turn around, okay wait, now… aim…

Designer A: [INTS]   Why's it not working?

Designer B: [HAN]   Did you pull the trigger?

Designer A: Yeah.

Designer B: Ah…

Designer A: [INTS]   It's being weird, let me just try…

Designer B: [INTS]   I think maybe the controller is a bit laggy…

Designer A: [HAN]   Pretty sure I'm over there a little bit more…. there you go

Designer B: Ah nice

Designer A: [INTS]   I think I was just a little bit too close or something, ah it's just a little bit tricky

Designer A: [IDE]   Oh no, pressed the wrong button. I'm trying to build like… sides…

Designer B: [ACC]   Like a closed area?

Designer A: [CLA]   Yeah, like sides to it so people can be café-ing it here

Designer B: [DEV]   Yep. Do you think you're going to put a roof on it, or just leave it open?

Designer A: [JOK]   I could do a roof, it's just going to be difficult [laughter] I'm not very good at this.

Designer A: [DEV]   Okay here we go. How did I even do that other one? Oh there we go…. Ah no...

Designer B:	[VSZ]	Oh, it's way too big.
Designer A:	[INTS]	[laughter] I'm poor at this… oh god where have I gone?
Designer B:	[VSM]	Turn around, turn around, yep.
Designer A:	[VSM]	Ah, gone too far
Designer B:	[VSM]	Maybe go to the left
Designer A:	[IDE]	Yep, just got to get into a vantage point.
		Should have started with the outdoor playground.
	[VSM]	Okay, maybe if I go further back here its going to be easier.
	[DEV]	Maybe I should just make a roof
Designer B:	[INT]	I think if you stand vertically, like perpendicular to the shape…
Designer A:	[VSM]	… you mean like this…
Designer B:	[CLAS]	...yeah, so you can make it thinner
Designer A:	[CLAS]	Yeah… like here?
Designer B:	[DEV]	…yeah, that's what I'm doing now
Designer B:	[INT]	Go back to the menu… sweet
Designer A:	[NRT]	Yes, come on, got to get the angle… oh god [laughter]
Designer B:	[NRT]	It's pretty tricky
Designer A:	[CLAS]	Um… I don't know, what do you think, do you think my design is good?
Designer B:	[EVA]	It's pretty good
Designer B:	[INT]	Hmm… I can't see it
Designer A:	[JOK]	[laughter] nah, I'm talking to him…
Designer B:	[VSM]	Maybe make something different on this side…
Designer A:	[ACC]	... this side, yeah just cause it's easier aye [laughter]
Designer B:	[IDE]	I think it's because it's the corner of the room and it closes…
		Ah, I've got an idea lets make a pillar…
Designer A:	[ACC]	Oh yeah…
		…here
Designer B:	[VSP]	…like columns...
Designer A:	[INTS]	... and a pillar… lets see if we can get rid of that, I don't like it anymore. It's too difficult – die.

Yeah, lets make some pillars and then we can make a roof. Oh god, ah, back.

[IDE] So, if we make a pillar there, ah nah, oh that's okay. We'll just leave that there for now.

[VSP] Make another pillar here, then we'll try build a roof.

Designer B: [ACC, INS] I think you'll probably have stand a bit higher, nah, that's good.

Designer A: [ACC] I did it! (06:02)

Designer B: [ACC] Ah, not bad.

Designer A: [EVA] Ah, yes!

Designer A: [VSP] Now we've got a roof, um, problem is the roof isn't actually far enough for the whole thing but we'll accept that, actually I might …

Designer B: [ACC] Ooh, cantilever

Designer A: [VSP, VSM] Ah yeah, it's starting to look like building almost. What does this look like is I step back a bit?

Designer B: [VST] Looks like a little shop

Designer A: [JOK, VSP] Yeah like a shop [laughter] maybe we should build a back wall to it.

Designer B: [IDE] Or we could leave it open, so…

Designer A: [ACC] Yeah true, but we need to fill this in or else we're going to get the elements you know

Designer B: [ACC] Yep

Designer A: [ACC] Yep, we can leave it open but, I agree.
(07:00)

[VSM] How do I get further that way though, oh I see what I need to do, it's just…

[INTS] It's not working, what's the method, what angle? I need to be over here aye?

Designer B: [ACC, DEV] Umm… that's good. Or you can just stand on top of the other building.

Designer A: [DEV] There you go, if I go like this and drag it… whoa that was weird…

Designer B: [NRT] I think sometimes the controller stops working.

Designer B: [NRT] Oh you got it…oh

Designer A: [DEV] Nice, I can probably delete that guy now, that mistake. It's scary because you might accidently delete the part you didn't want to delete. There you go.

[EVA] Okay, I think we've got our shop…

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Designer B:	[EVA, DEV]	Yep, and now move onto the…
Designer A:	[EVA]	…adult playground, yeah
Designer B:	[EVA]	…sweet.
Designer B:	[VSM]	Oh what the, where you at?
Designer A:	[VSM, JOK]	Woah [laughter] I'm inside the building, inside

the wall. Oh no, where have I gone?

Designer B:	[VSM]	I thought you, ohh…
Designer A:	[VSM]	Oh, its over there!
Designer B:	[VSM]	Across the road, yeah now you're good.
Designer A:	[VSM]	Oh no now I'm inside a wall again… eh oh
Designer B:	[VSM]	Where you? Oh, you're under the ground!
Designer A:	[VSM]	Am I?
Designer B:	[VSM]	Yep, ah now you're good
Designer A:	[JOK]	[laughter]
Designer B:	[NRT]	Sweet.
Designer A:	[NRT]	Okay, okay …
Designer B:	[VSM]	Is this the site?
Designer A:		Uh…
Designer B:	[VSM]	Nah, I think it's, oh wait
Designer A:	[VSM]	Wait where is it?
Designer B:	[VSM]	Where are you?
Designer A:	[JOK]	[laughter]
Designer B:	[VSM]	Oh, I think you're standing on top of the building you

made?

Designer A:	[INTS]	Am I?
Designer B:	[NRT]	Oh not it's not
		I'm not sure…
		Yeah you were!
Designer A:	[INTS]	Yeah I was! Is the building aye?! Okay, okay, now we're

good.

	[CLAS]	So now we've got our shop…
Designer B:	[CLA]	It looks pretty good. (09:01)
Designer A:	[EVA]	It actually looks kinda like a real structure [laughter]
Designer B:	[CLA]	Yeah, not bad.

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Designer A: [IDE]   Okay, I reckon we need to make something a bit more interesting than just straight blocks aye

Designer B: [VSP]   Hallow core!

Designer A: [ACC]   Yeah, yeah [laughter] that's exactly what I was thinking.

                                     So, like maybe we'll…

Designer B: [VSS]   Which side do you think is the entrance to your park?

Designer A: [VSP]   Ooh this is not what I thought it was but that's cool, oh we could make like a step, you know like…

                     [NRT]   …is that you Keegan? Trying to stay silent.

Designer B: [JOK]   [laughter]

Designer A: [DEV]   I'm trying to make like …

Designer B: [ACC, DEV]   … yeah some steps goes up, nice, nice. Maybe like a …

Designer A: [INTS]   … ah it's lagging, come on, come back to life

Designer B: [VSS]   … a balcony in the air, oh shit

Designer A: [INTS]   Oh god, the controller has gone all like

Designer B: [INTS]   Ah it's coming back

Designer A: [NRT]   Oh it's back to life okay. Sweet so, a lot of this is getting in the right position before you begin hey

Designer B: [NRT]   Mmm…   (10:11)

                     [IDE]   Oh, I like this idea, it goes up and…

Designer A: [CLAS]   Yeah, and what do you reckon, what's the final…

Designer B: [INS]   …maybe you can make a roof top thing they can chill out…

Designer A: [ACC]   …oh yeah…

Designer B: [CLA]   …they walk up and they chill on the top.

Designer A: [ACC]   … that's a good idea.

Designer A: [VWS]   So, we'll make one more I reckon and then we're tall enough

Designer B: [VWS]   Yep. Nice.

Designer A: [IDE]   Maybe a new shape, cause – what - did I change shape or did that.

                     [JOK]   Ah that sucks, look how thin it is [laughter]

Designer B: [REJ]   Aw like a sheet of paper

Designer A: [INTS]   [laughter] yeah, need to delete that – oh no where's my controller gone – Eh oh…

Designer B:	[INTS]	…ah there you go…
Designer A:	[11.06] [INTS]	…ah we're back.
		Ah come on, it's gone…
Designer B:	[INTS]	I think it's just the controller…
Designer A:		Yeah
Designer B:	[INTS]	Wait let me see if the…
Designer A:	[VTL]	Ah, wait, it's just confused about where it is [referring to the controller] cause it's like way over here
Designer B:	[NRT]	Oh! [Seth bumps controller against studio wall]
Designer A:	[JOK]	[laughter]
Designer B:		[laughter]
Designer A:	[INTS]	Okay, I think it's fixed itself
Designer B:	[INS]	Delete,
Designer A:	[REJ]	Nah, I'm trying to go add
Designer B:	[ACC]	Oh okay
Designer A:	[INT, HAN]	Ah, I want to go delete don't I - sorry I forgot what we were even doing
Designer B:	[INTS]	It's not moving around…
Designer A:	[NRT]	... yeah, it's not responding correctly, there you go it is now – oh but then it gets stuck.
Designer B:	[NRT]	Oh, no – Keegan would you mind coming to have a look
Designer A:	[VTL]	The controller keeps getting stuck.
	[VSS]	Ah, man that tree actually has wind
Designer B:	[VTL]	[laughter] Oh yeah. I thought the wind only works on the newer version
Designer B:	[VTL]	I added some wind… (11:59)
Designer A:	[NRT]	…Sneaky wind. So, it keeps happening that like I press this and - oh now that you came along it's working again.
Designer B:	[NRT]	Maybe it needs you to standing here
Designer A:	[NRT]	Oh, really, is that the thing?
		It's that one and that one
Designer B:	[NRT]	Oh shit, maybe I need to, sit on the ground?
Designer B:	[NRT]	Just on the chair
Designer A:	[NRT]	Oh yeah, you must be right because it's good now

Designer B:	[NRT]	Ah it's just me blocking the force
Designer B:	[INS]	Just like one either one or two
Designer B:	[ACC]	Whoa, nice.
Designer A:	[VSP]	It's a different shape,
Designer B:	[VSP]	it's a half arc
Designer A:	[DEV]	I want to get rid of that, ah I forgot that we need one more step.
Designer B:	[VSP]	Stairway
Designer A:	[VSP]	What was that one I had – it was like an octagon or something like this one
Designer B:	[VSP]	Multi-gon
Designer A: (13:04)	[VSP]	Hopefully I didn't make that thin like the other one
Designer B:	[VSP]	I think it worked out alright
Designer A:	[]	Ah!
Designer B:	[INTS]	Ah! Oh no. [laughter]
Designer A:	[VTL]	I trying to make steps, Keegan…
Designer B:	[VTL]	… Oh, I see…
Designer A:	[IDE]	… and then I going to make a rooftop experience up here.
Designer B:	[REJ]	Try and stand on the last step you made…
Designer A:	[ACC]	Yeah that's probably better aye
Designer B:	[ACC]	... and then – oh nice!
Designer A:	[ACC]	Yes.
Designer A:	[14.02] [VSZ]	And then I can delete that. Yeah, you're right, it's much better from up here – oh I forgot to hold.
	[VSZ]	Ah it's too far away – I'll just try and kill it by making it smaller.
	[VSM]	It's good enough, it's a bit far away but…
Designer B:	[IDE]	A big jump
Designer A:	[REJ]	...we've got no time to be pedantic
Designer B:	[NRT]	Oh, you can move it if you need to
Designer A:	[NRT]	can you? How?
Designer B:	[NRT]	Stand on that step…
Designer A:	[NRT]	the small one?

Designer B:	[NRT]	… and select the – jump into the menu
Designer A:	[NRT]	Oh, perfect
Designer B:	[NRT]	find the move tool; scale things as well if you need.
Designer A:	[NRT]	Oh, so I can make it smaller – can you move it – ah, if I had known that
Designer B:	[VTL]	We should have done more training…
Designer A:	[JOK]	[laughter]
Designer B:	[NRT]	But you're getting there
Designer A:	[IDE]	Yeah we got it now, so I can build my platform.
	[EVA]	Oh have you seen my building? This is the cafeteria / bar
Designer B:	[NRT]	Oh nice!
Designer A:	[15.07] [IDE]	Hmm, what can I do… what can I… put the big one over here (soft speech talking to himself)
Designer B:	[CLAS]	Are they the platform?
Designer A:	[ACC]	Yeah
Designer B:	[INS]	Make a bridge in-between it.
Designer A:	[ACC]	Yeah
Designer B:	[ACC]	Nice.
Designer A:	[IDE]	Okay, I need to make a flat platform. Ah shit, I put it way over there.
Designer B:	[ACC]	Nah, it's good
Designer A:	[16.03]	Come on boy, get there, get there!
	[VSM]	You just really want to be able to walk in this environment aye. Like you just want to be able to like, step, instead of having to do this awkward, you know, it feels unnatural aye.
Designer B:	[ACC]	Yep
Designer A:	[VSM]	Ah, I can just grow this things aye – so I'll just stand over here. This is starting to get a little bit like – oh my god – am I actually standing on something. Okay, so now we've got that shape I can go – move it – can I not move it sideways? Ah
Designer B:	[NRT]	Oh
Designer A:	[DEV]	Nice
Designer B:	[CLAS]	Mean
Designer A:	[VTL]	Maybe I need to move it… How come I can't move it sideways, Keegan? Is that not possible. Do I just have to come at it from an different angle?
Designer B:	[NRT]	Potentially. Start pulling it in one direction.

Designer B:	[JOK]	Ah [laughter]
	[NRT]	It might snap that way
Designer A:	[INS]	…pull…

Designer B: [INS] Ah! I think it's just the surface you selected. Maybe you need to select the side surface, yeah …

Designer A:	[17.00] [NRT]	Ahh…
Designer B:	[VTL]	… to make it left and right.
Designer A:	[INTS]	Oh oops, was the wrong button, shit Pull it this way
Designer B:	[INTS]	Did it work?
Designer A:	[INTS]	Yep

Designer A: [NRT] Yeah yeah, you're totally right. So then if I want to make to longer then I have to come over here and connect it to that guy.

Designer B:	[NRT]	Ah …
		But that's the move though
	[VTL]	… you should you the push/pull function
Designer A:	[NRT]	The what?
Designer B:	[VTL]	The 'push' and 'pull'
Designer A:		Ah
Designer B:		Um…
Designer B:		Ah…
Designer A:	[VTL]	Push pull
Designer B:		Yep
Designer A:		Push

Designer B: [VTL] And that will allow you to grab an edge and basically just extrude it

Designer A:	[VTL]	Like this?
Designer B:	[VTL]	Yep
Designer A:		Ah I see - ah - this is what I want.
	[IDE]	I wanna go, bam.
	[ACC]	Obviously this is defying the laws of physics but its

okay.

Designer B:	[ACC]	Okay
Designer A:	[TKQ]	So now
Designer B:	[IDE]	You got to connect this to the, ohh!

Designer A:	[EVA]	It's too low but we can probably fix that
Designer B:	[ACC]	Yep (18:00)
Designer A:	[EVA]	Let's have a - we need to have a look at what we've built here.

Ah maybe - ah no that's pretty sweet - that's actually pretty sweet. Ah actually I like it like that – its good.

So now people can go along …

Designer B:	[ACC]	… boom …
Designer A:	[VSS]	They can climb up here …
Designer B:	[ACC]	… boom …
Designer B:	[IDE]	… steps …
Designer A:	[ACC]	Boom boom
Designer B:	[DEV]	One more
Designer A:	[IDE]	Ah actually we need - that's a little bit – it's a bit of a hazard there [laughter]
Designer B:	[ACC]	Nah, people just need to take risks hey
Designer A:	[IDE]	[laughter] it's a bit of jump aye, nah I'll help them out, it's a little bit hazardous.

We'll put a different shape in there

Maybe we'll put like…

Designer B:	[IDE]	Put the first one, the arc
Designer A:	[CLAS]	The arc?
Designer B:	[INTS]	The top left
Designer A:	[CLAS]	This thing?
Designer B:	[ACC]	Yeah
Designer A:	[ACC]	Okay
Designer B:	[IDE]	Ah, I think
Designer A:	[NRT]	Ah
Designer B:	[VSM]	Maybe the other direction
Designer A:	[CLAS]	What do you mean, like… (19:00)
Designer B:	[VSP]	Like, the arc
Designer A:	[CLAS]	Like along here?
Designer B:	[REJ]	Nah, like the arc - 90 degree rotates? So, if you …
Designer A:	[IDE]	Wait, so what do you mean, like that way? No
Designer B:	[REJ]	Yeah, nah, the other way

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Designer A:	[IDE]	So like, this way
Designer B:	[ACC]	Ahh… maybe make this way and then rotate it
Designer A:	[CLA]	Ah yeah
Designer B:	[VWS]	Do you know what I mean?
Designer A:	[CLAS]	Ah yeah, yeah make it like that
Designer B:	[ACC, INS]	Yeah, and rotate
Designer A:	[DEV]	Oh, and them move it – how do I rotate- ah yeah rotate
	[NRT]	Why can't I get you?
Designer B:	[ACC]	Actually looks fine.
Designer A:	[EVA]	Yeah, it's a little bit weird, maybe we want to move it down. I can't seem to grab it from here though, maybe I need to get down there.
Designer B:	[INTS]	It's not selecting
Designer A:	[NRT]	Its un- selectable, that's okay
Designer B:	[20.00][NRT]	Shit
Designer A:	[INTS]	Oh well, so people can – how do I move again, ah yeah, bam …
Designer B:	[VSS]	… and they walk on this
Designer A:	[ACC]	… boom
Designer B:	[INS]	Access the roof
Designer A:	[ACC]	And now I've got – boom…
Designer B:	[NRT]	Mean
Designer A:	[NRT]	Umm… should we switch?
Designer B:	[NRT]	Do you think you're finished?
Designer A:	[VTL]	Yeah, I feel like I'm running out of ideas. I'm getting a slight little bit of a headache [laughter]
Designer B:	[JOK]	[laughter]
Designer B:	[VTL]	You've got motion sickness
Designer A:	[VTL]	Yeah just from the thing
	[EXA]	Yeah what do you think?
Designer B:	[EVA]	I like it
Designer A:	[JOK]	[laughter]
Designer B:	[VSP]	I think it's providing some nice shade
Designer A:	[VSS]	Yeah yeah, see like the bar tenders, they come back here …

Designer B: [VSS]   Some good shaded area

Designer A: [VST]   You know like, this is where they hang out, you know this is where they're tending bar

Designer B: [VSS]   It's providing like a bit of a covered walkway as well

Designer A: [21.00] [VSS]   Yeah yeah, like I think in reality you'd put some chairs and what not up there

Designer B: [IDE]   What do you imagine, um, you could have down lighting at night

Designer A: [ACC]   Oh, yeah, I think this is a café by day – you know …

Designer B: [NRT]   Oh yeah, multi-functions?

Designer A: [VST, VSS]   Yeah, yeah; and during the day it's a kid playground – which you would obviously build more playground act things, its just real difficult to actually; well I'm crap at this more so.

                   [VTL]   Yeah, I think we should swap, I feel like from the small amount I saw you using it, you're about to do some good shit … compared to me.

Designer B: [NRT]   Ah, that what you did is pretty good.

Designer A: [JOK]   [laughter]

Designer B: [NRT]   Like the whole step up idea

Designer A: [NRT]   [laughter] yeah that was a good part

----------------------------- start of designer change-over dialogue -----------------------------

Group Three: Option 7

Version 2: Transcribed by Keegan Davis

Source File: < Voice 005.m4a >

Round One:

	[00:00]	Muffled speech	
Designer B:	[00:25]	[NRT]	Try walk forward Sam. Yeah, yeah now you're good.
		[JOK]	[laughs] You can try building something!
			There you go
		[VSP]	What are you trying to build?
Designer A:	[01:02]	[TKQ]?	Can I delete some stuff?

Designer B:	[01:06]		Maybe?
	[01:12]	[VSS]	Oh, so you're going to build in there?
	[01:19]	[AAR]	Umm, I think they're both available plots. Okay,

hmmm

	[PAU]		
	[01:43]	[JOK]	[laughs] So destructive, Sam
			Ah, here we go …
	[PAU]		

	[02:38]	[VSZ]	Alright. What's the massive square?
Designer A:	[02:41]	[CLA]	Umm… a building I guess. I'm thinking of having

(inaudible) on the park side rather than the street side

Designer B:	[03:16]		Ah, there we go.
	[03:23]	[VSZ]	Alright, That's really big
	[03:28]		(inaudible)
Designer A:	[03:30]	[VSZ]	I think bigger would be good

	[PAU]		

Designer B:	[04:31]	[EVA]	Ah, I thought you meant to do that.
	[04:36]	[VST]	So is that going to be a roof of some description or… ?
Designer A:	[04:39]	[CLA]	It's supposed to be the building exterior. Supposed to be

Designer B:	[04:54]	[VST]	You made a floating shipping container — oh, now it's

a building, nice.

	[05:24]	[JOK]	I'll be honest, Sam I was expecting more pyramids by

now.

[05:34] [NRT]   You know how Russians have those kind of like mini pyramids on their roofs, you know? There's probably a word for that and I butchered that entire conversation.

	[06:20]	[TKQ]		Did you want to two separate buildings?
Designer A:	[06:22]	[CLA]	Um, no

Designer B:	[06:52]	[INS]	Maybe just try make a new one.
	[PAU]		

Designer B:	[07:47]	[ACC]	Oh there you go — ah, that's cool.

	[07:54]	[DEV]	Actually, you need some things that make sure it won't fall-down.
Designer A:	[08:00]	[JOK]	Some physics?
Designer B:	[08:03]		Yeah maybe.
	[08:07]	[ACC]	That's pretty cool.
	[08:11]	[VSS]	What would you have under there?
Designer A:	[08:11]	[DEV]	Um, I guess you could put some café seating…
Designer B:	[08:18]	[VSS]	So it's out of the sun…
Designer A:	[08:21]	[ACC]	Yeah
Designer B:	[08:23]	[VSS]	Because it's Wellington, you probably want to figure out some wind breaks
Designer A:	[08:28]	[DEV]	Yeah, just a giant wall around the entire building
Designer B:	[08:35]	[JOK]	[laughs] Yeah, just a really big wind break
Designer A:	[08:43]	[EVA]	But it's Karori though so it's not too windy
Designer B:	[08:44]		Yeah, true.
	[08:50]	[DEV]	You'd probably want — yeah — though, if you did a wind break you could do some form of heating so in the winter it would be nice, yeah
Designer A:	[08:56]	[EVA]	It's an outdoor building though so not really for people that are getting old ?
		[PAU]	
Designer B:	[10:00]	[ACC]	Oh yeah nice, oh.
	[10:08]	[CLAS]	Is that going to be a, like a ledge — yeah, yeah,
	[10:21]	[IDE]	Oh, you could have a roof top garden or something
Designer A:	[10:24]	[ACC]	Yeah, I guess you could,
Designer B:	[10:26]		Or just something on the roof.
		[PAU]	
	[10:58]	[CLAS]	Is that the attempted ledge there or?
Designer A:	[11:01]		Erm, where?
Designer B:	[11:02]		Left, [cross communication] there
Designer A:	[00:03]	[VWS]	Left, that's the um, top level [cross communication] of the — that was the ledge I was making before
Designer B:	[11:02]		Ah, yeah, yeah
	[11:15]	[CLA]	So that's the new one there? That's not so bad though.
Designer A:	[11:21]	[CLA]	That wasn't what I was intending
Designer B:	[11:24]	[CLAS]	Oh, where you going to have another ledge there?
Designer A:	[11:33]		Yeah, just like a small little (inaudible)
		[VTL]	Yeah, yeah — I don't know how you'd do that though
		[INS]	Would it be easier to just delete it, or?

Designer A:	[11:46]		not sure
	[11:51]	[INS]	Ah, yeah, just —put that, yeah…
		[PAU]	
Designer B:	[12:21]	[CLA]	What's the plank thing you have there?
			(inaudible)
Designer A:	[12:50]		(inaudible)
Designer B:	[15:53]	[JOK]	Yeah, now you can start with pyramids
	[13:03]	[JOK]	Yeah, that's right. I was thinking like a

medieval Russian castle

| Designer A: | [13:08] | [JOK] | We don't need that petrol station, do we? |

| | | [Laughter] | |

| Designer B: | [13:18] | [JOK] | Yeah, It's Elon's [Musk] new petrol station. |
| | [13:39] | | Do you want to deal with that pink thing |

there?

| | [13:44] | | Yeah, just leave it, or is it supposed to be |

there?

Designer A:	[13:46]	[CLAS]	I think it supposed to be there,
Designer B:	[13:53]	[REJ]	Ah, just leave it.
Designer A:	[13:56]		Yeah, it's fine.
Designer B:	[14:08]	[ACC]	This is a cool area.
	[14:13]	[CLAS]	Ah, are you going to try make a door?
Designer A:	[14:15]	[CLA]	Yeah, just an opening… (inaudible)
Designer B:	[14:25]	[JOK]	[laughs] Did you just make 10 times rapid fire

pyramids?

Designer A:	[14:29]	[JOK]	[laughs]
Designer B:	[14:30]	[JOK]	I think you're multiplying pyramids
	[14:37]	[ACC]	Ah, there we are.
Designer A:	[14:49]	[VTL]	(inaudible) Um, I mean you can't really get too in detail

with this tool so that's… (inaudible)

Designer B:	[14:52]		Yep, alright — oh take things (inaudible)
		[PAU]	
	[15:05]	[JOK]	[laughs]
Designer B:	[15:35]	[ACC]	Ah, nice
	[15:43]		Erm, you wanna give me a go, just tell me

what to do

[15:56] *End of Group A, Round One. Tom and Sam switch places*

| Designer B: | [16:04] | | (inaudible) |
| | | | You're on top of something inside of something |

Round Two;

| Designer B: | [HAN] | Okay what have we got? |
| | [CLAS] | What do you think Sam, which one do I pick? |

Designer A:	[IDE]	Try the pyramid.
Designer B:	[EVA]	So this is the roof here?
Designer A:	[ACC]	Yeah
Designer A:	[CLAS]	So you're trying to make a roof top garden?
Designer B:	[INTS]	Um… what do I do?
	[CLAS]	What are you trying to do?
Designer B:	[VTL]	Shift it,
Designer A:	[VTL]	Pull is resize,
		Oh.
	[NRT]	No.
	[VTL]	Did I make that?
		I'm just a wrangler.
	[VTL]	If you click on this it will disappear.
	[ACC]	Alright, that's good enough for now.
	[TKQ]	How do you make a garden?
	[JOK]	A pyramid garden?
	[VTL]	Yeah, that's a good question. What can we use here to

make a garden in here?

	[INTS]	You're moving the entire building now.
	[VTL]	Is there a CTRL + Z?
	[HAN]	Did I mess up anything?
		No it's fine now.
	[CLAS]	Do you like my tree?
	[VTL]	It's be like a group thing and I can just copy and paste

it everywhere.

	[INS]	Maybe try grab the bottom.
	[NRT]	This is way better than the time I tried VR drunk. I

made me real sick from that one

	[ACC]	Okay, I think that's ready.

Appendix C

Ethics Documents

The research has been approved by the Victoria University of Wellington Human Ethics Committee 0000025705.

Information Sheet

INFORMATION FOR PARTICIPANTS

You are invited to take part in this research. Please read this information before deciding whether or not to take part. If you decide to participate, thank you. If you decide not to participate, thank you for considering this request.

Who am I?

My name is Shuva Chowdhury, and I am a Doctoral Candidate in Architecture at Victoria University of Wellington. This research project is work towards my thesis.

What is the aim of the project?

We question how a virtual participatory design process allows people to design their own neighbourhood. Our research develops a decision-making process for laypeople to participate in the design discussion. It offers stakeholder collaboration and engagement in immersive virtual environments. Our research is experimental and explores an alternative integrated approach to investigate urban character in a design procedure. The research produces 3D building blocks and urban open spaces.

This research which is a part of the National Science Challenge (NSC) - Building Better Homes, Towns and Cities (BBHTC): Shaping Future Neighbourhood, explores an alternative integrated approach to investigate urban form in a design procedure.

This research has been approved by the Victoria University of Wellington Human Ethics Committee 0000025705.

How can you help?

You have been invited to participate in visualising your future neighbourhood. If you agree to take part, you will be given a design tool for trial; then you will be asked to complete a survey. The survey will ask you questions about 'how does this virtual tool help you together to visualise

your future neighbourhood?' The survey will take maximum one hour. The participant will be stopped by me after the time passed. You will be requested three people at a time to participate. All of the participants will remain seated and only the time of VR experience you may wish to stand or remain seated. The charrette steps and durations are:

1. Orient the participant with the controller of the virtual tool – 15 mins

2. The participants will design the 3D buildings in computer by collaborating with others, where only one person will wear the VR head set (while seated/standing) and other two person will discuss. Max 10 mins slot for each, all together– 30 mins.

3. Post- charrette questionnaire survey – 5 mins.

The event will be audio recorded.

What will happen to the information you give?

This research is confidential. This means, your identity will be removed from any publication. The event photos will be published with no face recognition. By answering it, you are giving consent for us to use your responses in this research. Your answers will remain entirely unidentifiable for this reason; please do not include any personally identifiable information in your responses.

What will the project produce?

The project will produce 3D buildings in computer and some event photos with no face recognition. The project will also produce articles, conference papers and a PhD thesis.

What are your rights?

The voluntary nature of participation, including that they are free to decline to participate, or to withdraw from the research at any practicable time, without experiencing any disadvantage.

If you have any questions or problems, who can you contact?
If you have any questions, either now or in the future, please feel free to contact either:

Student:

Name: Shuva Chowdhury

E: shuva.chowdhury@vuw.ac.nz

Supervisor:

Name: Prof. Marc Aurel Schnabel

Role: Dean Architecture and Design

Faculty Office

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School: Architecture

T: 044636095

E: Marcaurel.schnabel@vuw.ac.nz

Human Ethics Committee information

If you have any concerns about the ethical conduct of the research you may contact the Victoria University HEC Convenor: Dr Judith Loveridge, email hec@vuw.ac.nz, phone (04) 463 6028.

Consent Form

CONSENT TO PARTICIPATE

This consent form will be held for 1.5 year.

Researcher: Shuva Chowdhury, School of Architecture, Victoria University of Wellington.

- I have read the Information Sheet and the project has been explained to me. My questions have been answered to my satisfaction. I understand that I can ask further questions at any time.

- I agree to take part in an audio recorded discussion.

I understand that:

- I may withdraw from this study at any point before the event date, and any information that I have provided will be returned to me or destroyed.

- The identifiable information I have provided will be destroyed on 31st December 2019.

- Any information I provide will be kept confidential to the researcher and the supervisor.

- I understand that the results will be used for a PhD dissertation and reports for academic publications and presentation to conferences.

- My name will not be used in reports, nor will any information that would identify me.
- I would like to receive a copy of the final report and have added my email address below.

Signature of participant: _____

Name of participant: _____

Date: _____

ontact details: _____