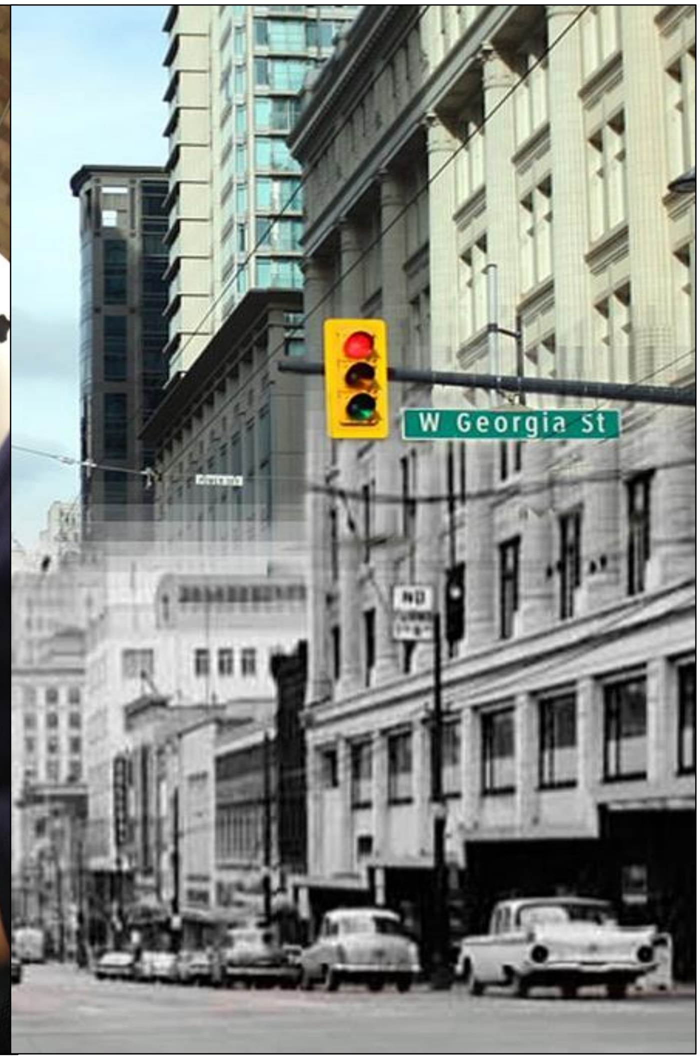

Virtual Reality as a Visualization Tool for Public Participation in Planning Practice

Exploring Existing and Potential Uses of Immersive, Non-Immersive, and Augmented Reality Systems

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Supervised Research Project | School of Urban Planning, McGill University

Abstract

Within the discipline of urban planning, the evolution of professional practice with regard to public participation has grown from simply informing the public about planning problems and solutions to collaborating with the public in participatory decision-making and/or empowering the public with the responsibility for final decision-making. As public participation increases, it has become increasingly important to be able to quickly and effectively communicate the expertise and insights which professional planners can share. Urban planning policy and bylaws have historically been heavily based in the medium of text and the challenge of visualization is a major barrier to helping the public understand proposed changes to the urban form – be they in setbacks, new height allowances, or the addition of different types of housing stock.

The potential of virtual reality (VR) technology to overcome barriers to visualization has been recognized for many years. However, limitations in cost, accessibility, and immersion have restricted opportunities for implementing VR tool use in the development process. Given recent advances in VR technology, new opportunities exist to move beyond recognizing the conceptual potential of VR and acknowledge VR's full potential as a visualization tool for public participation.

This research offers background material on the evolving themes of technology and public participation in planning practice, as well as a survey of VR use both in the profession and further afield. Furthermore, as the use of non-immersive VR is already prevalent throughout planning practice (although not necessarily recognized as such), some guidance is also provided for those interested in building on that expertise to make use of immersive VR in participatory action research (PAR).

Résumé

La pratique professionnelle concernant la participation publique dans le domaine de l'urbanisme a évolué au fil du temps : du simple fait d'informer le public au sujet de problèmes de planification et de solutions proposées, elle a mené à la collaboration de la population dans les prises de décision et/ou la responsabilisation de celle-ci dans une prise de décision finale. Avec la participation croissante de la population, il s'avère de plus en plus important pour les urbanistes d'être en mesure de communiquer rapidement et efficacement leurs expertises et leurs connaissances. Sur le plan historique, les politiques et les règlements en urbanisme ayant dans le passé surtout été diffusés en format imprimé, le défi de la visualisation représente un obstacle majeur à la compréhension par le grand public des modifications proposées à la forme urbaine, que ce soit au niveau de la marge de reculement, des nouvelles hauteurs permissibles ou de l'ajout de différents types de parcs de logements.

Le potentiel des technologies de la réalité virtuelle (RV) à surmonter les obstacles de la visualisation est reconnu depuis plusieurs années. Toutefois, les limites au niveau des coûts, de l'accessibilité et de l'immersion ont restreint la possibilité d'intégrer l'utilisation des outils de la RV dans le processus de développement. Compte tenu des progrès réalisés dernièrement dans le secteur des technologies de la RV, de nouvelles opportunités existent désormais pour progresser de la simple reconnaissance du potentiel conceptuel de la RV à l'acceptation du plein potentiel de la RV en tant qu'outil de visualisation à des fins de participation publique.

Cette recherche présente des renseignements généraux sur les thèmes évolutifs de la technologie et de la participation publique au niveau de la pratique de l'urbanisme, ainsi qu'un aperçu de l'utilisation de la RV au sein de la profession et dans d'autres domaines. D'ailleurs, étant donné que l'emploi de la RV non immersive est déjà répandu dans la pratique de l'urbanisme (quoique ce fait ne soit pas toujours reconnu), quelques orientations sont fournies à l'intention de ceux qui désireraient s'appuyer sur cette expertise de RV immersive à des fins de recherche-action participative.

[Translation : Linda Poirer, Helen Yawnghwe]

Acknowledgements

The supervised research project (SRP), the capstone project of our Master's degree in Urban Planning at McGill, is really the result of the cumulative work and support of everyone in the program and at the School of Urban Planning. The ideas, discussions, and guidance which inform my own SRP come from conversations with professors and staff, readings recommended by fellow students, late night work sessions on studio projects, insightful classes, and even several parties with classmates where friends and significant others kindly tolerated their revelry being overrun by planning discussions. While the choice of words in this text may be the work of a single author, the background context which informs the content could only arise from the support of a very large team.

I must first extend a very special thank-you to Professor Brown for agreeing to be my supervisor, for giving guidance and sharing insights and experience, and for accommodating various unexpected developments along the way. Furthermore, by giving me the opportunity to present to his Planning Methods class on the role of technology in urban planning, Professor Brown also helped me to better situate my explorations of virtual reality and urban planning within a much larger context.

Many thanks are also due to Professor Richard Levy. His recognition (in the 1990s) of the visualization value that 3D urban modeling would come to have, helped me to make the case that the visualization value of virtual environments has yet to be fully explored. As a second reader, his insights also helped to greatly refine key parts of the paper's structure. Any gaps or confusions that remain cannot be attributed to Professors Brown and Levy's guidance but are solely due to my own choices and omissions.

Towards the end of this paper, I outline a proposed participatory active research (PAR) project involving the use of VR as a visualization tool. After discussing preliminary ideas with various parties – including Professor Michael Jemtrud, who helpfully was the first to direct me towards research methods for HCI (human-computer interaction) – it became clear that a full-fledged undertaking of such a formal research project would require more time and resources than could be accomplished within the scope of this paper. However, much of the practical structure of the included proposal can only be attributed to the feedback of everyone who participated in those informal demonstrations I was able to host – some of whom even valiantly and eagerly volunteered despite their susceptibility to motion sickness.

Many thanks are due to: my fellow School of Urban Planning students (Classes of 2013, 2014, and 2015) who participated in exploring several virtual environments, along with a multitude of family members and friends (including my parents' Tuesday night group), and the occasional serendipitous demonstration participants – such as Professor Renee Sieber and some of her colleagues and graduate students in the Geography Department – particularly Ana Brandusescu, who graciously took the time to share her own experiences with technology and environment modeling. As with my star participant, my grandmother, the varied insights and life experience of all these participants served to provide a richer context for discussions about how advances in VR might change our world for better or worse.

En route to the completion of all degree requirements, thanks are also due to the efforts of Professors Raphaël Fischler and Lisa Bornstein in guiding our Studio initiation, as well as the many other professors and instructors at, or associated with, the School who led our other explorations (in no particular order): Ahmed Elgeneidy, Richard Shearmur (a paper I wrote on telework for his Urban Economics course was the basis for suggesting VR's effects on telework as a direction for further research in Chapter Nine), Nik Luka (a paper I wrote on post-war reconstruction in Beirut for his class introduced me to the case for path dependency in the reconstruction of Berlin that is used in Chapter Two), Madhav Badami, Ray Tomalty, Cameron Charlebois, Marc-André LeChasseur, Heather Braiden, and Paul Lecavalier. I would also like to thank Anand Sood and Gladys Chan for their service in taking care of us students. Last, but not least, I could never have imagined that I would learn so much or share so many memorable experiences with as great a group of people as the students from our year who I am now proud to count amongst my dearest friends: thanks to each and every one of you for making it so hard to leave!

A very special thank-you is also due to friends and family who read drafts. Particularly in the case of the heritage planning scenario in Chapter Six, I needed reassurance that my audience could understand what I was describing. Linette, Onjana, and Shane: you rock, thank you for your critiques and sorry for not being able to answer all your questions about what these new technological advances will mean!

I am indebted to my mother and Linda Poirer for the French translation of my abstract and, finally, I must also thank my parents and sister for enduring the years of existential angst surrounding my philosophical questioning and endless love/hate relationship with technology.

Keharn Yawnghwe

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List of Acronyms and Abbreviations

General Terms

2D	Two-Dimensional
3D	Three-Dimensional
CAD	Computer Assisted Design
CAO	Chief Administrative Officer
CAVE	Cave Automatic Virtual Environment
CMC	Computer-Mediated Communication
BIM	Building Information Modeling
GIS	Geographic Information System
GUI	Graphical User Interface
HCI	Human-Computer Interaction
HMD	Head-Mounted Display
ICD	Inter-Camera Distance
ICT	Information and Communication Technology
IED	Improvised Explosive Device
IPD	Inter-Pupillary Distance
IP	Intellectual Property
IPS	Interactive Patient Scenarios
LiDAR	Light Detection And Ranging
MDP	Municipal Development Plan
MFIPPA	Municipal Freedom of Information and Protection of Privacy Act
MUD	Multi-User Dungeon (alternately, Dimension or Domain)
MMO	Massively Multi-player Online
MMORPG	Massively Multi-player Online Role Playing Game
MOO	MUD, Object-Oriented
NGO	Non-Governmental Organization
PAR	Participatory Action Research
PPGIS	Public Participation Geographic Information Systems
PPP	Playful Public Participation (**Note:** usually, Public-Private Partnership)
PTSD	Post-Traumatic Stress Disorder

RCM	Rational Comprehensive Model
RIG	Residential Infill Guidelines
SLAPP	Strategic Lawsuit Against Public Participation
SRP	Supervised Research Project
UI	User Interface
VR	Virtual Reality

Institutions, Organizations, and Projects

ACM	Association for Computing Machinery
APA	American Planning Association
CERN	European Organization for Nuclear Research (**Note:** originally, Conseil Européen pour la Recherche Nucléaire)
CIP	Canadian Institute of Planners
CPI	Centre for Public Involvement
FCA	Federation of Citizens' Associations of Ottawa-Carleton
FiVE Lab	Ford's immersive Vehicle Environment Lab
IAP2	International Association for Public Participation
ICMA	International City/County Management Association
ISS	International Space Station
JPL	(NASA’s) Jet Propulsion Laboratory
MFA Boston	Museum of Fine Arts Boston
NASA	National Aeronautics and Space Administration
OCPM	l'Office de consultation publique de Montréal
OMBI	Ontario Municipal Benchmark Initiative
PARC	(Xerox’s) Palo Alto Research Center
SIGGRAPH	(ACM’s) Special Interest Group on Computer Graphics and Interactive Techniques
TEI	Text Encoding Initiative
ULCC	Uniform Law Conference of Canada
UNESCO	United Nations Educational, Scientific and Cultural Organization
USCICT	University of Southern California’s Institute for Creative Technologies

Technical Formats and Protocols

COLLADA	COLLAborative Design Activity
FBX	Filmbox
HTML	HyperText Markup Language
HTTP	HyperText Transfer Protocol
SMS	Short Message Service
VRML	Virtual Reality Modeling Language
WWW	World Wide Web

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If the chaos of the nineties reflects a radical shift in the paradigms of visual literacy, the final shift away from the Lascaux/Gutenberg tradition of a pre-holographic society, what should we expect from this newer technology, with its promise of discrete encoding and subsequent reconstruction of the full range of sensory perception?

– Roebuck and Pierhal, *Recent American History: A Systems View*.

[An excerpt from William Gibson's short-story, "Fragments of a Hologram Rose," 1977.]

Preface

The allure of virtual reality (VR) has captured the imaginations of many and proposals to use VR for visualization are not new to urban planning. In most cases, however, the limitations of the technology have made widespread adoption impractical. So why return to an exploration of VR as a visualization tool? My inspiration for researching VR as a visualization tool for public participation was based on two factors: the perception of a growing need for visualization and the arrival of new and affordable VR technology.

My appreciation of the importance of visual communication developed during a planning internship with the City of Edmonton in early 2013. As part of a planning policy unit investigating the potential scope of initiatives to promote infill housing in line with the City of Edmonton's *Ways* policy documents – chief among them its municipal development plan (MDP), the *Way We Grow* (City of Edmonton 2010), a series of preliminary interviews was conducted with stakeholders both internal and external to the City of Edmonton. Noticeably, throughout these interviews, the challenge of visualization was often raised as a barrier to infill development. This was not due to the absence of design guidelines; a manual of residential infill guidelines (RIG) exists with a wide variety of visual examples (City of Edmonton 2009). Rather, according to feedback from various stakeholders, communities and individuals are apparently often unable to easily envision what development might look like in their own neighbourhoods.

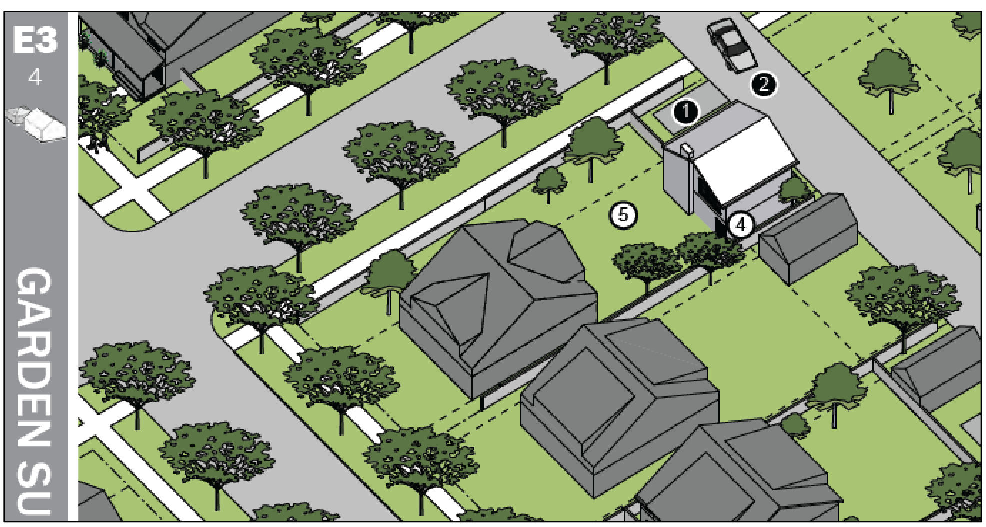

Figure 1, A visual aid from the City of Edmonton's residential infill guidelines.
[Source: "Residential Infill Guidelines" (City of Edmonton 2009)]

Meanwhile, as a technological hobbyist, I was waiting to receive a prototype development kit for a new immersive VR system called the Oculus Rift. With some limited personal experience in educational and independent game development (web-based scripting and applications, Flash, C++, Python, etc.), I had contributed to a crowd-funding campaign for the Rift during the summer of 2012 after hearing about the positive attention it was receiving from key industry veterans. Without knowing exactly what to expect, it was clear from general comments that this advance in VR technology would have a significant impact beyond the game development industry. When my prototype arrived, I had the idea to build a basic three-dimensional (3D) model of my neighbourhood to explore in VR and soon realized the incredible potential that this type of immersive VR system has to offer to professional planners.

In a similar way, the Rift's adoption by medical researchers and process engineers quickly telegraphed its value as a VR system with widespread applications beyond its original purpose as a gaming headset. In fact, a controversial but significant move occurred just prior to the completion of this paper when Facebook bought Oculus (the developers of the Rift) for $2 billion USD. The full effects of that purchase are likely to have far-reaching consequences in the spread of VR technology.

Together, these two factors – a perceived need of additional visualization tools and new advances in affordable VR technology – inspired me to investigate how VR can directly address visualization challenges in urban planning. As I explored the topic further, I realized that planners already use some forms of VR extensively and that it would be helpful to produce a paper on the state of use of VR in professional practice with additional recommendations for extended application to public participation.

A brief introduction to VR terminology and systems

While a later chapter provides a more detailed history and discussion of virtual reality, it is probably helpful for most readers to familiarize themselves with some basic terms and concepts at the outset. Although the acronym VR will be used predominantly in this paper, *virtual reality* will sometimes be written out for added clarity (as in this section). It is also important to note that the term *virtual reality* (VR) can be used either in reference to the virtual reality medium – the way we communicate with virtual reality – or the virtual reality system – the combination of computer hardware and software which enable the virtual reality experience (Whyte 2002).

Whyte identifies three characteristics which define the medium: virtual reality is *interactive*, *spatial*, and *real-time*. Put simply, the medium of virtual reality allows users to interact with a three-dimensional (3D) environment with little to no delay to their actions. Though there may be some variation in the degree to which each characteristic is present, the medium of virtual reality is best used when it serves to provide insight into the relationship between the visualization and the larger context of information in the built environment (Whyte 2002).

Virtual reality systems can vary greatly in form due to different compositions of hardware and software, but fall into three categories depending on how the systems deliver the experience of virtual reality:

> *Immersive systems* are meant to completely immerse the user in the experience, as suggested by their name. As Whyte notes, immersive systems have typically required specialty hardware in the form of head-mounted displays or custom-built rooms. The new virtual reality technologies which inspired this paper (such as the aforementioned Oculus Rift) fall into this category of immersive systems but use hardware costing hundreds of dollars instead of tens of thousands, or hundreds of thousands of dollars.
>
> *Non-immersive systems* have always been cheaper than immersive systems and as a result have become commonplace although few users now think of their experience as virtual reality. Whyte observes that these systems were sometimes called window-on-a-world systems because users effectively look through the window of a computer screen or display into the virtual environment with which they are interacting. Today, practically all forms of interaction which we have with 3D environments on a computer (e.g. using Google Street View, playing 3D games, using any 3D modeling software) can be called non-immersive virtual reality systems.
>
> *Augmented reality systems* marry the real and virtual. Augmented reality systems were originally somewhat static in a temporal sense. As described by Whyte, augmented reality systems typically incorporated captured video of the real world along with interactive computer imagery. In this sense, the dynamism of interacting with an immersive or non-immersive virtual reality system was augmented by real imagery but that imagery was largely pre-recorded. Today, the real world imagery in augmented reality systems is also real-time. Smartphone applications, such as the Museum of London’s Streetmuseum app, which let you hold up your

phone on a present day street and see a historic version of the same (Museum of London 2013), or the innovative and controversial Google glass product, are examples of modern augmented reality systems which incorporate a real-time blend of real and virtual.

Figure 2, Directions explaining how to use the Museum of London's Streetmuseum app. [Source: "Streetmuseum" (Museum of London 2013)]

A brief note about holography

As a sister technology to VR, holography also promises incredible potential for simulated reality applications (perhaps most famously imagined in *Star Trek*'s holodeck). However, although innovative technology companies (e.g. Apple) have actively invested in the research and development of holographic technology for many years, the complexity of the technical challenges involved in delivering true 3D holography (i.e. not Pepper's Ghost illusions such as those used to 'revive' dead musicians like Tupac or Michael Jackson at concerts) are unlikely to be overcome in the immediate future for most applications. While not covered in this research, holography could also offer immersive environments (e.g. holodeck) or augmented reality contexts (e.g. interactions with holographic 3D objects on a desk). Professor Levy notes that this area is already being heavily explored by the US military (Levy 2014). Some examples of such initiatives are the VIPE (Virtual Immersive Portable Environment) Holodeck (Northrop Grumman 2013) and the Infantry Immersion Trainer (IIT) (Lockheed Martin 2012).

Chapter 1: Introduction

Virtual reality is here. Many of its current forms may not yet meet our expectations or demands but new advances are breaking into the mainstream that can deliver heralded applications. From allowing people to envision what laneway housing or adaptive reuse might look like in their neighbourhoods, to presenting planners with an immersive in-situ record of sightlines, the full range of applications to planning practice is waiting to be discovered. In fact, whether planners realize it or not, limited forms of VR have already been widely adopted in everyday planning practice. When we navigate through three-dimensional (3D) models in computer assisted design (CAD) software packages (e.g. Autodesk's AutoCAD or Trimble's SketchUp), or use 3D visualization in a geographic information system (GIS) (e.g. esri's ArcGIS), we are making use of VR systems. These VR systems, however, only reflect a small amount of the potential that further advances in VR technology will bring; in time, many aspects of our everyday lives will present further opportunities to support public participation in planning practice.

Aim and context

This paper's general aim is to understand how VR is already being used in planning practice and to explore the additional opportunities and challenges for participatory planning that surround those VR applications which have yet to be adopted.

As students in urban planning, we are continually reminded that our work as planners (in the broadest sense) involves a reflective consideration of trends and patterns in time and space – as they influence both the lives of individuals and society – with the purpose of anticipating and responding to changing circumstances and needs with the objective of serving the greater good. This research is happening against a backdrop of rapid technological change and a call for increased public participation. The convergence of these issues – the role of technology and public participation – encompasses many of the questions which will face the wider adoption of VR in urban planning.

VR will soon be able to deliver on much of its potential as a visualization tool but that is only the beginning of immersive VR's potential. A fully sensory experience can allow planners to even better communicate functional changes in natural and human environments such as noise impacts, weather patterns, or odour dispersion modeling from mills or wastewater treatment plants (WWTP). These experiences can be harnessed to ensure that everyone is equally equipped to envision and understand the future ramifications of the decisions made in planning scenarios.

Research objectives

Through a review of the literature, the research objectives of this paper are to present the current state of research on VR in planning, to explain how we have arrived at this juncture, and to demonstrate how VR's application as a visualization tool might be applied to common planning scenarios, such as: 1) how immersive VR can contribute to universal accessibility planning; and 2) how immersive VR can offer greater opportunities to experience comparative case studies firsthand with virtual site visits to remote (and even international) locations.

Nature and importance of the research

With reference to Ranziger and Gleixner, Doyle et al. observe that the work of the planner and urban designer is "to plan, model and simulate the outcome of a given process or development" (Doyle, Dodge and Smith 1998, 138). This work of information gathering and analysis does not mean that planners must approve of or endorse the process or development being studied, but instead suggests that studies are undertaken with the aim of encouraging a better understanding of the elements involved. For Doyle et al., the visual qualities of traditional physical models or large-scale plans aid decision-making, democratize planning, and help to disseminate or convey ideas. To this end, they argue that these same tools may be replaced in future with other means to achieve the same aims – all facilitated by innovative technological advances.

Ultimately, Doyle et al. foresaw a greater adoption of geographic information systems (GIS) and VR in the modeling and analysis of the built environment. Yet while GIS has become an integral part of the planning process, VR does not appear to have seen the same advances. Why is this? While some of the answer is likely incidental, there are aspects of VR which pose particular challenges. In addressing the merits and shortcomings of VR as they pertain to its application as a tool for planners, the greatest challenge to presenting the case for the relevance and necessity of such a discussion is perhaps the hype which has surrounded earlier attempts to introduce VR technology.

The challenge of expectations for new technology

One of the greatest difficulties in championing a young technology is the burden of delivering on early promises which were made when imaginations ran wild. The challenge of advocating for the use of VR in urban planning is no different (Whyte 2002); nevertheless, a great deal of its potential has already been realized. It is now time to plan new explorations: to ask what else VR can accomplish, to mark recognized barriers, and to spot dangers which may still lie ahead.

The familiar history of navigation from ancient times, from dead reckoning through the evolution of celestial navigation to our modern positioning technologies, marks the trajectory of technological innovation (Muller, Randell and Djiallis 2003). Individual technologies rise, fall, and find reinvention. Strengths are maximized and weaknesses minimized in subsystems with specific purposes that draw on particular efficiencies. Today's smartphone owners may give limited thought to how the location-based services they use work, but a modern use of dead reckoning – a basic positioning system – can still be found in inertial navigation systems (Wang, Min and Yi 2008).

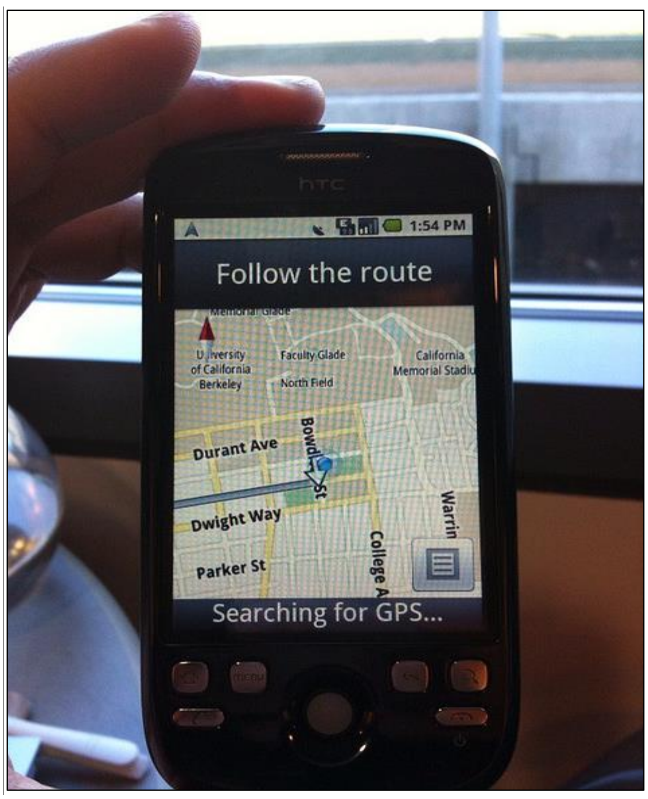

Figure 3, Combined navigation systems in a smartphone.
[Source: "Woohoo! Free GPS nav from Google" (dailylifeofmojo 2009), License: CC BY 2.0]

Similarly, although early aspects of VR technologies such as Virtual Reality Modeling Language (VRML) and resource-intensive cave automatic virtual environment (CAVE) immersion systems may have appeared to falter, fail, and disappear from the discourse of planning tools, VR has largely lived on. For example, Virtools, a product originally used in CAVE systems (Levy 2014), was acquired by Dassault Systèmes and brought under its 3DVIA brand. While "3DVIA Virtools is no longer available for purchase" (Dassault Systèmes 2013), its essence lives on in Dassault Systèmes' various virtual visualization offerings. In fact, contemporary applications of VR have taken on varied forms which many planning practitioners now take for granted as everyday tools of their trade.

While the use of VR as a visualization tool is already a critical component in planning practice, the full potential of its application to empower the public in participatory planning has yet to be harnessed. My hope for this paper is twofold: first, readers will finish this paper feeling that they understand the issues and context surrounding VR applications in planning; and second, that they will be inspired to think of new ways in which VR can promote public participation.

Proof of concept

Although the best window of opportunity for research on the use of VR as a visualization tool for public participation in planning is not yet here, it is rapidly approaching. The technological advances and industry changes which have been happening concurrent to the writing of this paper already allow for very affordable immersive VR experiences which were unimaginable even two or three years ago. There are, however, still some important obstacles to the unrestricted use of new VR systems, including a wide variability in participants' susceptibility to motion sickness. In preparation for expected advances which will redress such limitations, this paper includes a methodology for a proposed participatory action research project, explaining why certain research methods were chosen along with an analysis of the expectations for the results.

Paper structure

This paper is divided into ten chapters. Chapter One's general introduction leads into the main body of the paper (Chapters Two through Seven) which can be roughly divided into two parts. The first half (Chapters Two through Four) establishes the rise of public participation and the need for visualization in the larger planning context, while the second half (Chapters Five through Seven) presents the case for the existing and potential uses of virtual reality in planning practice. Following the main body, Chapter Eight and Chapter Nine focus on future work and Chapter Ten brings the paper to its conclusion.

Setting the stage for the first half of the paper, Chapter Two presents the historical context of technology and planning. After exploring how concerns about the sometimes technocratic nature of the rational comprehensive model (RCM) led to a paradigm shift in planning culture, the chapter discusses how direct access to technology can empower people. This final focus on technologically-empowered actors in civil society leads us into Chapter Three.

Chapter Three examines how our contemporary planning culture encourages public participation and is supported by democracy as an alternative model of planning. The chapter describes how technology is supporting the evolution of public participation through initiatives such as open data and e-government and finishes by evaluating public participation in Canada. As we segue into Chapter Four, the observation is also made that the availability of data is not the same as data-accessibility.

Chapter Four emphasizes the importance of visualization in communicating ideas and promoting civic engagement. However, as visualization takes on greater importance in public participation, there is also a need to address questions of representation. Abstract information and data must be presented in a manner which is appropriate to their context. The chapter closes with an acknowledgement of the potential which VR holds in allowing us to use our imagination to explore our existing context in new ways.

Launching into the second half of the main body, Chapter Five reveals how VR quietly became an everyday part of our lives. Briefly addressing the changing nature of ontological questions, the chapter considers how the increasing complexity of our interactions with technology has fueled research into human-computer interaction (HCI). A review of VR systems and how they can cater to a diversity of users sets up the background for the next chapters.

Chapter Six presents a wide variety of contemporary VR uses and explains how augmented reality may not actually need to be categorized as a VR system type. Instead, with the help of a number of scenarios, the chapter explores how immersive and non-immersive VR systems may actually allow for augmented reality as a shared subtype. Finally, a hypothetical scenario is presented which demonstrates how each of the different VR systems could be used together by individual actors who would experience very different perceptions of presence.

Chapter Seven reviews the already widespread use of non-immersive VR in planning practice and suggests potential immersive VR applications that planners might also find valuable. Given that some planning practitioners may not realize that they already use VR, the chapter covers several common planning tools that are examples of non-immersive VR systems. Briefly addressing how urban modeling is finding momentum outside of planning practice, the chapter finishes with suggestions for future immersive VR applications as the technology grows more robust and becomes even more accessible.

Chapter Eight presents the outline of a proposed participatory action research (PAR) as mentioned in the previous Proof of Concept section. While immersive VR is very close to reaching its potential, the technology is still developing at a rapid rate and will only begin to stabilize within the next couple of years. The chapter and its recorded observations are shared as a rough guide for those interested in undertaking a future PAR project based around an immersive VR system.

Finishing with the main body and the outline for a PAR project, Chapter Nine offers suggestions for more general directions for further research into VR applications in planning. Although VR's nascent ascent has so far focused almost exclusively on its visual qualities, fully immersive VR offers the opportunity for even richer experiences. As Professor Renee Sieber suggested when the initial project was first being considered, recorded samples of background noise at several intersections could be integrated into an immersive VR experience so that participants can experience how varying degrees of urban intensification might alter the soundscape with which they are familiar.

With the vast potential offered by such suggestions, and in anticipation of a growing adoption of immersive VR, Chapter Ten brings this paper to a conclusion. As demonstrated throughout this paper, there is a clear case for VR as a visualization tool for public participation in planning practice. Furthermore, with further advances in VR still forthcoming, there is little doubt that planners must, at the very least, be prepared to tackle those new opportunities and challenges that a growing adoption of VR will bring.

Chapter 2: The historical context of technology and planning

The vast multi-disciplinary potential of VR brings with it added complexity. In discussing the impacts of VR as a new technology, planners must consider both how VR is used as a tool in planning and whether planners are prepared to confront the wider technological changes which may accompany its use. In this light, it is important to discuss the historical context of technology and planning.

As addressed in the introduction, and as described by the Canadian Institute of Planners (CIP) or the American Planning Association (APA), planning is widely understood to be about securing the well-being of communities and the enrichment of people's lives (APA 2013, CIP 2014). In CIP's code of professional conduct, the planner's responsibility to the public interest not only requires a concern for natural and human environments but also a commitment to providing opportunities for meaningful participation and education (CIP 2014). If faced with prejudiced opposition, we must respect the criticism that planners have at times acted as technocrats and in ways which cannot be reconciled with those mandates.

From antiquity, ordered principles have guided the growth of human settlements with a view to general security and prosperity. Early settlements were informally shaped by the importance of food storage and natural defenses, but scientific discovery and the evolution of dominant social orders led to formalized codes for town planning. The famous Law of the Indies, where every Spanish colony in the New World was ordered to be built as a completely new city according to a carefully recorded set of specifications and pattern (Mundigo and Crouch 1977), is a famous example of how standardization in sanitation and social order could be enforced.

From the military precision of Roman engineering to Haussmann's widening of the boulevards in Paris, the relationship between planning and government has been such that one may ask, as does Bishwapriyal Sanyal: "Why focus on the planning culture of a city, region, or nation if, indeed, its political economy is what ultimately shapes the particular characteristics of its planning endeavours?" (Sanyal 2005, 4). While the specific intent of Sanyal's question is to prompt reflection on the effects of the growing interconnection of planning cultures in a global context, it draws out the issue of whose values shape planning. Although implicitly understood as a function of the profession, it is worth acknowledging that decisions made today will continue to affect many people in the years that follow.

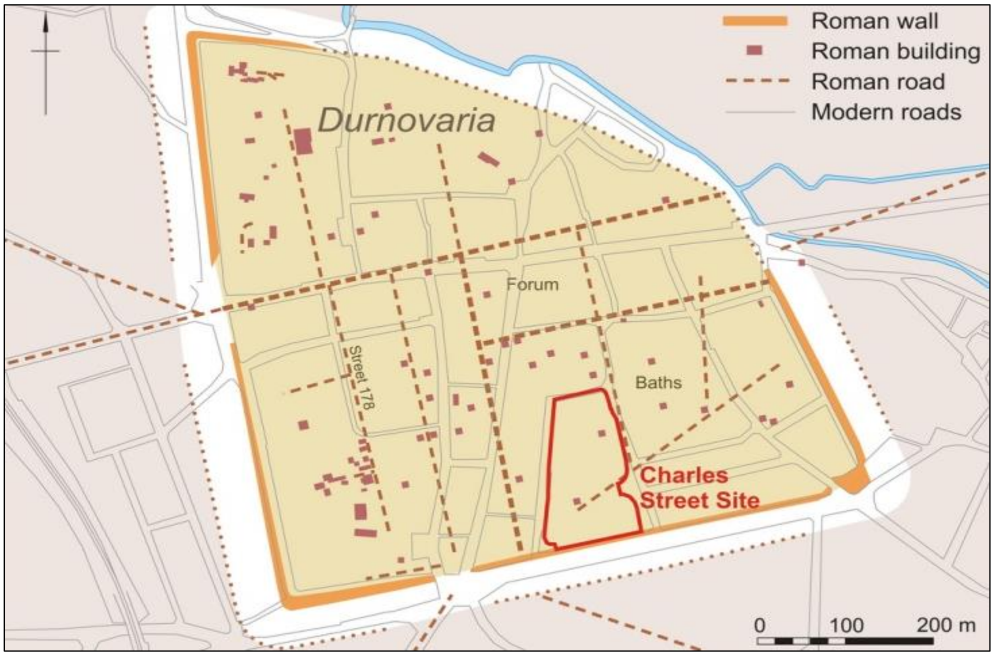

Figure 4, The march of time seen in underlying Roman road patterns in Dorchester England.
[Source: "Map of Roman Dorchester – Durnovaria" (Wessex Archaeology 2011), License: CC BY-NC 2.0]

One good example of the long term effects of planning decisions can be found in Brian Ladd's research on the relationship between urban planning and civic order in Germany between 1860 and 1914 (Ladd 1990). The pursuit of urban sanitation made the street a public place, which in turn gave municipal governments control of its use. It is hard to contest the argument that these developments ultimately did improve the health of the working class (Brown 2014), and thus can be seen as a positive application of technology in planning, but even these beneficial initiatives were not without unforeseen consequences.

As municipal governments gained political power in the late 1800s, their plans for municipal sewer systems unknowingly set the stage for the post-war reconstruction of Berlin after World War Two. Planners and architects who had envisioned a physical reconfiguration of the city found, when it came time to rebuild, that they were stymied by the fact that much of the invisible infrastructure below ground – sewers, water lines, etc. – was still largely intact (Ladd 1997). Consequentially, generations of Berliners have been impacted by the historical planning decisions of those original municipal governments which were made without any need or regard for public input.

The rise of technocratic planning after World War 2

Following the Second World War, the adoption of a mode of planning which prized a scientific approach came fully to the fore (Appelbaum 1977) and – due to the institutional and legal effects of large-scale reorganizations of resources and development – contributed to a homogenizing effect that entrenched the image of planning as following a singular path (Galloway and Mahayni 1977). The hallmark of such planning under the now disavowed rational comprehensive model (RCM) was to see the development of highways as a central tool to promote economic growth. Too often, as was the case in Montréal, the construction of these auto routes was also erroneously seen as an opportunity to eradicate social problems by razing low-income housing stock.

Figure 5, The demolition of the Faubourg à m'lasse in Montréal.
[Source: *Lost Neighbourhoods* (Ville de Montréal n.d.)]

In taking on the role of experts and custodians of specialized knowledge, intentionally or otherwise, some planners prized scientific advancement and efficiency at the expense of needs or interests overlooked by a model of technical rationality. Perhaps the epitome of this mindset, further tarnished by personal ambition, was New York City's famous yet infamous, 'master builder,' Robert Moses (Caro 1974). Known for both his significant contributions to New York as well as his dictatorial power over urban development and renewal in the city, Moses's brazen disregard for public opinion in his later campaigns set the stage for the protests in Greenwich Village which would bring Jane Jacobs's criticism of urban renewal to the fore. That there may also have been other planners seeking forms of sustainable development, as argued by Brown, highlights how planning grew in complexity as it was forced to address the inevitable tension between different societal values (Brown 2014).

A growing critique and shift in planning culture

The Death and Life of Great American Cities called for a diversity of housing stock and activities (Jacobs 1961), and contributed to a paradigm shift in planning culture driven by a growing criticism of planning and its results as "too technocratic, elitist, centralized, bureaucratic, pseudoscientific, hegemonic, and so on" (Sanyal 2005, 7). Sanyal suggests that the turning point for both industrialized and industrializing countries came in 1968, as critics – professional planners, activists, and academics alike – drew attention to the need for planning to be responsive to the public's needs first and foremost.

Later, in 1983, Donald Schön challenged professionals to consider how a narrow pursuit of technical knowledge leads to a focus on problem solving that often ignores context; he called for reflection in action (Schön 1983). Looking at how the tunnel vision of practice without reflection had led, in Schön's descriptive phrasing, to *a crisis of confidence in professional knowledge*, Schön and others issued a challenge to not abandon technology but to ensure instead that the tools and knowledge used by professionals are not hidden in a proverbial black box. It is this concern that is particularly relevant given the growing complexity and intricacies of computer technologies in planning and past failures resulting from a lack of information-sharing and co-participation.

Writing in 1987 about the exciting and unrealized potential of computer technology to offer new tools for professional planning practice, David Brown noted that, for all of the prospects that computers might provide in terms of flexibility, interactivity, and opportunities for cooperative planning, we should always be cognizant of the dangers of relegating planners' responsibilities entirely to the purview of new technologies. For without skilled human analysis, "these technologies can no more create a good plan than eye glasses can help an illiterate person to read" (Brown 1987, 92). Equally important for planners to consider is the reminder that new technologies may not immediately be available in a way that promotes accessibility.

Empowering people through wider access to technology

With the paradigm shift encouraging new modes of planning, came the expectation that planners should be less reliant on modern technology yet increasingly sensitive to cultural differences and the needs of disadvantaged groups (Sanyal 2005). Unfortunately, on occasion, this results in opposition to technology and hinders discussions about tool use and the potential for technology to enable deliberative democracy and participatory planning. Although the limited availability of technology can indeed be a social barrier (a valid criticism of VR or augmented reality in municipal planning if hinged on the need for participants to own smartphones or tablets (Cirulis and Brigmanis 2013)), if planners make themselves gatekeepers and deny civil society the potential use of technologies, they are being no less exclusive. In fact, while the costs of technological innovation may initially preclude equal access, the wider context which planners must consider is that the effects of such innovation are not static.

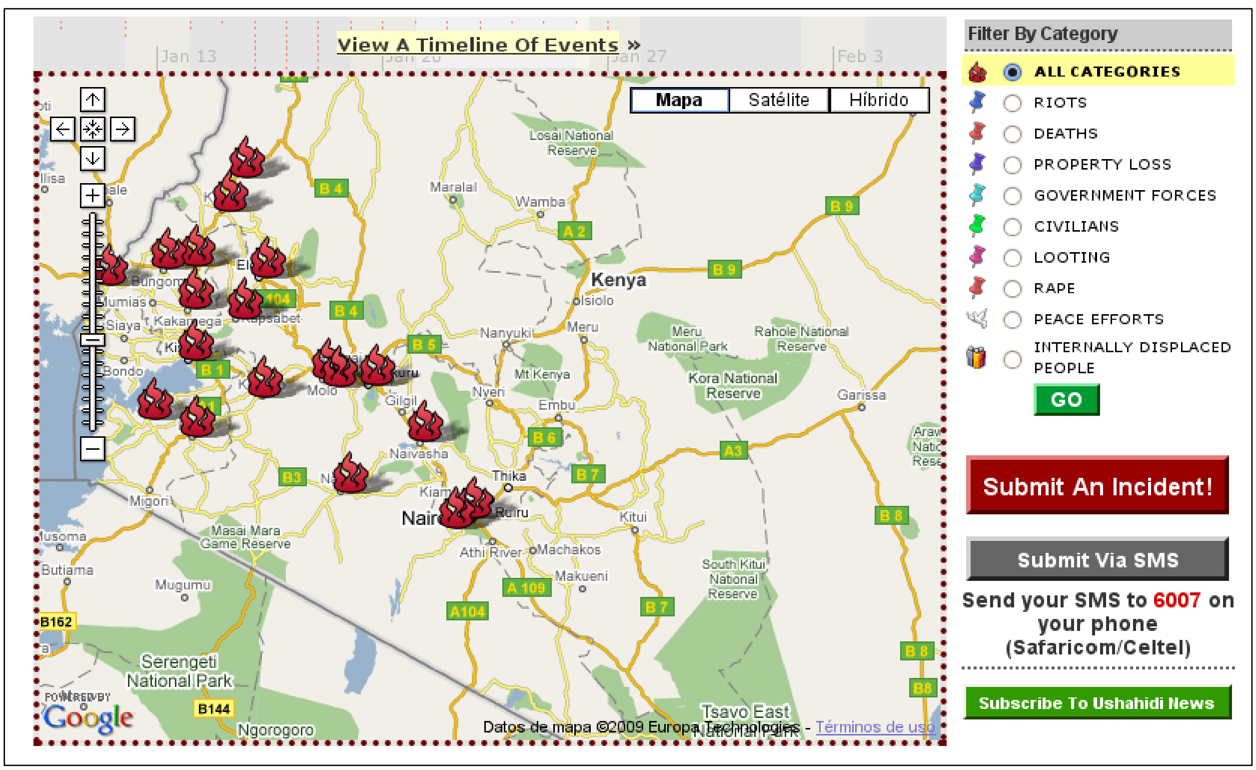

Figure 6, Incident mapping with SMS reporting during Kenya's 2008 post-election unrest. [Source: "ushahidi en Kenya" (Berrios 2009), License: CC BY 2.0]

Brown observes that, in working as a planner in less-developed countries, new technologies can permit communities to leapfrog over intermediate steps which were previously necessary (Brown 2014). For example, while cellular phones were once considered solely luxury items, there is now considerable discussion of the role they have played in supporting civil society movements in Africa and Asia. Information and communication technology (ICT) initiatives which use text messaging (SMS: short message service) to organize grassroots human rights advocacy have been successfully implemented by many groups such as Fahamu, a non-governmental organization (NGO) focused on social justice in Africa (Dean, Anderson and Lovink 2013), and through web-based mapping platforms like Ushahidi (Ushahidi n.d.). These are both examples of technology empowering people to share information and take action where they are, rather than being used in a top-down system of governance. Holding on to this vision of individual actors working together to promote civil society and supported by technology, the next chapter explores the theme of democracy and public participation in planning practice and policy-making.

Chapter 3: Democracy and public participation

In North America, our modern understanding of planning culture is directly tied to our democratic system of government. Planning policies are largely guided by the same principles which are enshrined in all levels of government and subscribe to the same constitutional commitment to an equitable and egalitarian society. As such, it is natural for us to expect the language of our master plans to identify citizens as the intended beneficiaries of the mandates these plans set forth.

Furthermore, our expectation that citizens will be included in both the input and the outcomes of public processes extends far into the future. Our endorsement of principles such as sustainable development draws attention to the idea of a legacy to be passed on. A typical example of this view can be found in the first chapter of Montréal's master plan. Here, the Ville de Montréal outlines its planning approach as being "a balanced approach based on economic vitality, social equity, environmental preservation and respect for the needs of future generations" (Ville de Montréal 2004, 5). While this expectation for participation in local government and of future public benefits is now *de rigeur*, its roots lie in the past with America's Declaration of Independence.

When Alexis de Tocqueville visited America in the early 1830s and famously recorded his experience in *De la démocratie en Amérique*, he noted his great appreciation for 'la liberté communale' which gives local people reason to come together for the betterment of society. References to de Tocqueville which emphasize planning's support of democracy draw on his observation that the active use of municipal institutions – e.g. the town meetings and organization of local government – makes liberty both accessible and tangible to citizens, in the same manner that primary schools introduce and lead students into the wider exercise of their search for knowledge (Kaliski 2009). De Tocqueville believed that it was the strength of the independence of local residents which would act as a ward against despotism and guarantee a nation's liberty (de Tocqueville 1835).

Figure 7, The classic New England town hall meeting depicted in Norman Rockwell's *Four Freedoms*. [Source: early study for *Freedom of Speech* (Rockwell 1941)]

Who participates?

Although there is nothing wrong in aspiring to an ideal conception of civic-mindedness which would guarantee full public participation in planning, political theorists such as Charles Taylor have argued that understanding what is meant by civil society in the Western tradition is not straightforward (Seters 2008). In seeking clarity on the relationship between society and political order, Taylor underlines the need to distinguish between thought which follows John Locke and that which follows Montesquieu as our contemporary notion of civil society is comprised of both streams (Taylor 1995).

This is important to planners because we must be clear that we understand the difference between a call for public participation which recognizes society as existing beyond the political (per Locke) and that which defines society as purely political and thus only seeks to organize the distribution of power among the participants (per Montesquieu). It is outside the scope of this paper to wrestle in detail with the full implications of these political philosophies; however, in the view of this paper it is widely accepted (if not always explicitly stated) that the model of public participation which is endorsed in planning practice is one which invites citizens to influence political policy yet which recognizes an identity outside of the political. In other words, our great hope is that we are committed to bearing a social responsibility to also work on behalf of those who cannot, or choose not to, participate.

One of the leadings responses to the failures in the 1950s and 1960s of the rational comprehensive model (RCM) was to argue for a greater emphasis on democracy and the direct involvement of citizens in planning practice. Many critics of the RCM, such as Appelbaum, called for the deprofessionalization of the role of the expert and advocated instead for citizens to be empowered and given the necessary skills to confidently address the everyday issues that affect them (Appelbaum 1977). However, as planners and other professionals moved away from presenting themselves as experts, it was also evident that giving everyone the opportunity for input did not mean that everyone would be correct in determining an appropriate course of action.

More recently, Emily Talen has argued that it is possible to move beyond relativism and to highlight good city form without returning to the failures of the RCM; her position is that, as planners, we need to have some conception of an ideal form but we also have to acknowledge that we cannot arrive at it by ourselves (Talen and Ellis 2002). Even if clear visualized ideals exist, Talen stresses that, in order for our work to be legitimate, it is necessary to balance our ideals with an inclusive process (Talen 2012).

The evolution of public participation

In 1969, Sherry R. Arnstein tackled the challenge of defining a typology of 'citizen participation' as part of the wider call for a more democratic approach to social policies in planning (Arnstein 1969). Describing her work, "A Ladder of Citizen Participation," as a provocative response to the controversial rhetoric and euphemisms being used in debates on urban renewal and anti-poverty efforts, Arnstein presented the argument that citizen participation is chiefly about recognizing citizen power but that concentrated power-holders can reduce public participation to tokenism or even ensure the public's non-participation in decision-making and implementation processes.

On the two lower rungs of the ladder, *manipulation* (rubberstamping policies in the wider name of the public) and *therapy* (subjecting citizens to the suggestion that they are at fault and need to be cured), citizen power is lost in non-participation. Continuing up the ladder, the next three rungs are familiar and common approaches to public participation: *informing* (a one way flow of information)*, consultation* (involving opinions but without the assurance they will be addressed)*,* and *placation* (giving a limited amount of power to token representatives). Arnstein refers to these as degrees of tokenism that simply do not go far enough.

The last three rungs are reserved for degrees of citizen power: *partnership* (a negotiated redistribution of power between citizens and power-holders), *delegated power* (the resulting placement of citizens in dominant decision-making roles), and *citizen control* (the full control of policy and resources by citizens). In presenting citizen control, Arstein notes that absolute control is non-existent within a national context but stresses that the intent is to position citizens to control negotiations. It should be clear that Arnstein acknowledges the validity of several criticisms of complete citizen control (including the potential for separatism and the balkanization of public services) but rests her case with the observation that other initiatives have failed to reframe the issues.

Almost fifty years later, our contemporary categorizations of public participation approaches owe a lot to Arnstein's ladder of citizen participation. The International Association for Public Participation (IAP2) offers a spectrum of public participation, widely used by organisations and governments, which communicate the different forms that public participation can take and explains how each form has different goals – from simply providing the public with information, to placing decision-making power in the public's hands (IAP2 2007). The spectrum presents each level of public participation as having an increasing level of public impact but does not stigmatize those lower levels which Arnstein described as degrees of tokenism. Regardless of the chosen approach, the use of virtual reality as a communications technology makes VR effective all along the spectrum. As will be discussed, diverse applications allow VR to serve as a visualization tool at various stages of design and implementation.

IAP2 Spectrum of Public Participation

International Association for Public Participation

Increasing Level of Public Impact →

	Inform	Consult	Involve	Collaborate	Empower
Public participation goal	To provide the public with balanced and objective information to assist them in understanding the problem, alternatives, opportunities and/or solutions.	To obtain public feedback on analysis, alternatives and/or decisions.	To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered.	To partner with the public in each aspect of the decision including the development of alternatives and the identification of the preferred solution.	To place final decision-making in the hands of the public.
Promise to the public	We will keep you informed.	We will keep you informed, listen to and acknowledge concerns and aspirations, and provide feedback on how public input influenced the decision.	We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how public input influenced the decision.	We will look to you for advice and innovation in formulating solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible.	We will implement what you decide.
Example techniques	▪ Fact sheets ▪ Web sites ▪ Open houses	▪ Public comment ▪ Focus groups ▪ Surveys ▪ Public meetings	▪ Workshops ▪ Deliberative polling	▪ Citizen advisory committees ▪ Consensus-building ▪ Participatory decision-making	▪ Citizen juries ▪ Ballots ▪ Delegated decision

Figure 8, A spectrum of public participation.
[Source: "IAP2 Spectrum of Public Participation" (IAP2 2007)]

Public participation and the rise of e-government

Satisfying the most basic approach to public participation (that of informing the public), information has become increasingly accessible due to the growth of information and communication technologies (ICT). Today, discussions surrounding public participation have spread into the area of electronic government (or e-government). The ability to provide government services and information to citizens on demand – supported by electronic infrastructure – has been promoted as an opportunity to make these processes more transparent. A growing recognition of the advantages provided by digital data storage formats (e.g. improved records management standards, or backup copies with negligible physical limitations), and the potential for input on public processes offered by the internet have made e-government increasingly popular.

Chief among the key factors which contribute to the potential of e-government is the idea of open data. Along with the general crisis of confidence in professionals during the 1960s and 1970s, came an increasing focus on transparency which encouraged a growing belief that certain information should be freely available to everyone. In Canada, this growing sense of the need for government accountability was marked first by the establishment of the Privacy Commissioner in 1977, and then by the Privacy Act, the creation of the position of Information Commissioner, and the Access to Information Act in 1983 (Canada 2013). These initiatives, and similar legislation in Europe and the USA, set the stage for the development of the open data movement and modern commitments to open government.

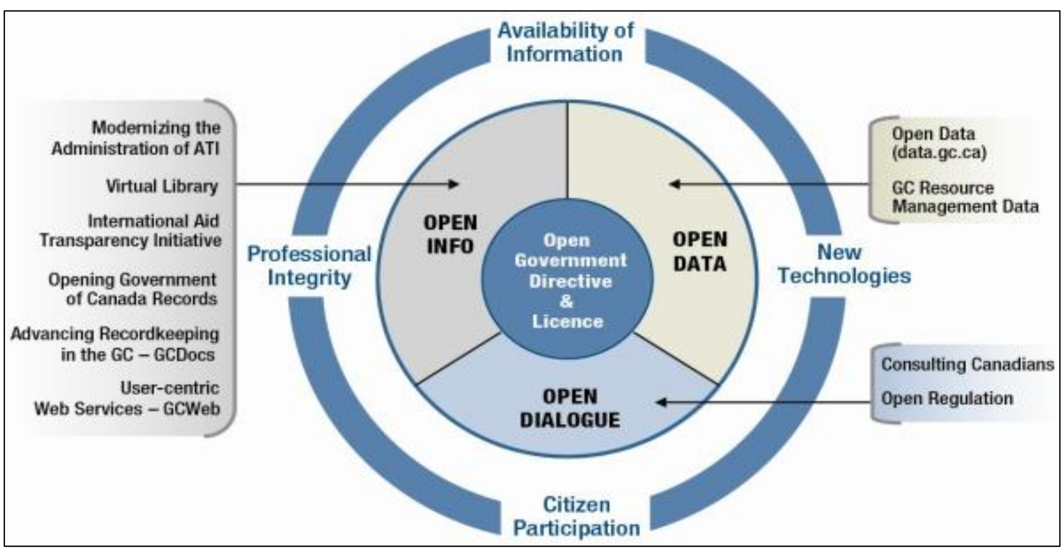

Figure 9, Canada's commitments to open government.
[Source: "Canada's Action Plan on Open Government" (Canada 2013)]

The most widely accepted definition of open data is “data that can be freely used, reused and redistributed by anyone – subject only, at most, to the requirement to attribute and share alike” (Open Knowledge Foundation n.d.). The salient points of this definition are: it emphasizes the availability and access of the data as a whole in an easily modified form; it can be reused and redistributed in a manner which allows different parts to be mixed; and it does not discriminate but is universally open to all (Ibid.). As can be seen in Figure 9, Canada's commitments to open government are portrayed as combining open information, data, and dialogue, in a manner which emphasizes professional integrity and citizen participation.

Whether the promotion of e-government is only rhetoric is a question that has persisted for some years; however, we may be failing to account for the time required for large-scale implementations that fit public needs. In an analysis of a survey on e-government targeting municipal governments with populations of over 10,000 that belonged to the International City/County Management Association (ICMA) in 2000, M. Jae Moon records that, of the 1,471 respondents (a 51% response rate), almost nine out of ten had a website for information dissemination or reference (Moon 2002). Beyond this first step, about 8% already had an e-government strategic plan for greater public integration and another 48% were planning for one (Ibid.). While Moon noted in his analysis of the survey that overall adoption was slow (with many municipalities only in the early stages of e-government), he also drew attention to the *‘very dramatic’* evolution of the preceding three years for the more established practice of having a website (Ibid., 429). He concludes cautiously, but optimistically, that while maturity may be limited by a lack of capacity and resources, growing commitments to these initiatives exist and that their full potential has yet to be realized (Ibid., 431).

Evaluating public participation in Canada

As laid forth by Arnstein, citizen power is necessary for public participation to rise above tokenism (Arnstein 1969). In this light, Levy questions how Canadian cities rate today and whether there is still only token engagement (Levy 2014). It is difficult to answer Levy’s question for every Canadian city without a formal system for ranking municipal governments but public service initiatives like the Ontario Municipal Benchmark Initiative (OMBI) may evolve to address that challenge.

While OMBI does collect and publish data on many municipal service indicators in an annual report (OMBI 2014), citizen engagement is only addressed to a very small degree. The initiative, which was originally led by the City Manager or Chief Administrative Officer (CAO) of its Ontario members (which include the City of Toronto), now also includes the City of Calgary and the City of Winnipeg, as well as the Ville de Montréal which joined on June 19, 2014 (Ville de Montréal 2014). Although citizen engagement is only included under the service area titled 'Clerks' with respect to municipal governments' responsiveness to formal Municipal Freedom of Information and Protection of Privacy Act (MFIPPA) requests (OMBI 2013), there may be some room in future to add other indicators for public participation.

Beyond municipal public service rankings, provincial efforts to protect public participation do exist in the Canadian context. The rise of the SLAPP (strategic lawsuit against public participation) has threatened public participation and has routinely evoked calls for anti-SLAPP legislation. As SLAPPs are primarily used to counter opponents of development by burdening them with drawn out lawsuits that are costly both in terms of time and legal fees, SLAPPs may be deemed frivolous under existing legislation but there are additional efforts to codify specific protections against such lawsuits.

A 2008 report on SLAPPS for the annual meeting of the Uniform Law Conference of Canada (ULCC) notes that, whereas relations between citizens are governed by the *Charter of Human Rights and Freedoms* in Québec (Québec 2014), anti-SLAPP legislation is often argued to be necessary because there are no constitutional guarantees for private relations in the rest of Canada (Pelletier 2008). While British Columbia was unsuccessful in keeping the anti-SLAPP legislation it enacted in 2001 and New Brunswick and Nova Scotia both introduced anti-SLAPP bills that were never passed (in 1997 and 2003 respectively) (Pelletier 2008), Ontario has since introduced its provincial Bill 83 which is now known as the *Protection of Public Participation Act, 2014* (Ontario 2014). As of April 16, 2014, Ontario's Bill 83 has passed two readings in the Legislative Assembly of Ontario and has been referred to its Standing Committee on Social Policy. While there have been negative reactions to Bill 83 from those who feel that only Québec has such legislation because allowing public dissent leads to inefficient development processes (Jervis 2014), it is probable that if the bill passes its third and final reading that other provinces may consider similar legislation in future.

In the absence of a framework to review the effectiveness of public participation and the challenges which have arisen from various initiatives, it is may be worth considering on a case by case basis how individual Canadian cities promote and integrate public participation. A relevant reference point for such a study can be found in a report submitted to Ottawa's Corporate Services and Economic Development Committee and City Council in September of 2003 which recommended the adoption of a Public Participation Policy and the creation of a Roundtable for Citizen Engagement (City of Ottawa 2003). Following the amalgamation of twelve municipalities into the new City of Ottawa in 2001, Ottawa had reviewed international, federal, and other municipal public participation policies for best practices.

With regards to municipal public participation policies, it was observed that very few municipalities in Canada had comprehensive corporate policies at the time of the 2003 report. Instead, citizen engagement was conducted on an 'as needed' basis when faced with controversial issues. Presenting two alternate paths to promoting and safeguarding public participation, the report makes note of how the approach of the City of Calgary and the City of Vancouver differed from that of the Ville de Montréal. Whereas the City of Calgary and the City of Vancouver both undertook initiatives to develop corporate policies and establish public engagement offices, the Ville de Montréal worked with the Province of Québec to establish L'Office de consultation publique de Montréal (OCPM) as an independent body.

Although it is outside the scope of this paper, there is still much research to be done on how effective public participation initiatives and policies have been in various Canadian municipalities. As such, the headings which follow contain brief details of current initiatives in a selection of Canadian cities as a point of reference. While there is no single standardized approach to public participation in Canada (as evidenced by this small selection), there may be common lessons which can be distilled:

Ottawa

According to the Federation of Citizens' Associations of Ottawa-Carleton, although Ottawa's City Council approved the previously mentioned recommendation for a Public Participation Policy and endorsed the creation of a Roundtable for Citizen Engagement on October 22, 2003 (City of Ottawa 2003), there has been no further evidence of the policy at work and the roundtable was not created (FCA 2014). However, the City of Ottawa approved a new *Public Engagement Strategy* in December 2013 (City of Ottawa 2013), and has since released a *Public Engagement Guidelines and Toolkit* draft (City of Ottawa 2014).

Montréal

As mentioned, the OCPM was created by the Ville de Montreal through provincial legislation to be an independent body. The OCPM notes that Montréal has a rich history of citizen participation which dates back to citizen assemblies and petitions which supported the protection of Mount Royal in 1860 (OCPM 2012). From its creation in 2002 through 2013, the OCPM led 111 public consultations and it continues to fulfill its mandate by engaging with a growing number of citizens each year (OCPM 2014). In keeping with the terms of the Charter governing its work, the OCPM also provides detailed annual reporting.

Toronto

The City of Toronto does not have a specific policy on public participation. Its *Briefing Book* (for the 2010 to 2014 term) includes only two pages which describe the role of the public in decision-making (City of Toronto 2011). These pages express commitments to a strong voice for residents, addressing barriers to participation, and transparent decision-making, but seem to suggest a prevalence of ad hoc processes over any standardized approach to public participation.

Edmonton

The City of Edmonton has taken a slightly different approach to public participation by partnering with the University of Alberta to create the Centre for Public Involvement (CPI). The CPI was first proposed in 2009 and has since contributed to both researching public involvement and running engagement initiatives involving the use of citizens' panels (CPI 2014). These have included its *Citizens' Panel on Edmonton's Energy and Climate Challenges* (CPI 2013) and its *Report on Citizen Panel Process & Recommendations* (CPI 2012) for Edmonton's *Food and Urban Agriculture Strategy* (City of Edmonton 2012).

A final note on using new technology for greater public participation

Today, as a result of municipal e-government initiatives and strategies, open data projects across Canada are actively working with data shared by municipal governments and transportation agencies to help improve public participation and make cities better. Separate from the work of Montréal's previously mentioned OCPM, in October 2011, the Ville de Montréal launched its open data portal (http://donnees.ville.montreal.qc.ca) and it has since been used by everyday citizens to create small projects such as a site that maps ongoing road construction in Montréal (http://zonecone.ca). However, while these projects provide a valuable starting point, their greatest burden often lies in the need to refine raw and relatively inaccessible text-heavy data. It is here that the importance of visualization comes to the fore; this can encompass everything from the relational systems modeling that IBM contributed to *The Portland Plan* (IBM 2011, City of Portland 2012), to public planning exercises with stickers and blocks. As will be addressed in the next chapter, visualization is a key part of civic engagement and an important way to facilitate communication in public participation.

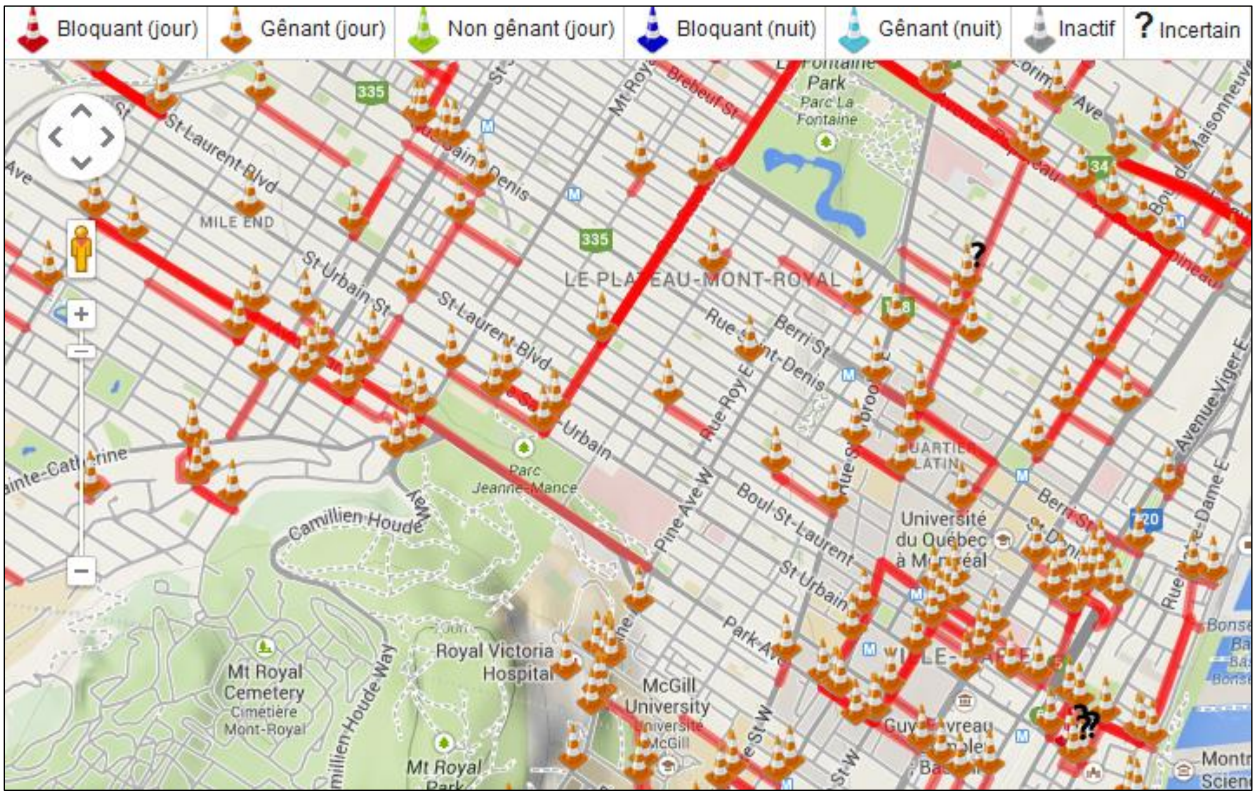

Figure 10, A screenshot of a construction mapping project for Montréal that uses open data.
[Source: "ZoneCone.ca" (Données ouvertes Montréal 2014)]

Chapter 4: The importance of visualization for engagement and communication in planning practice

In *Planning and Urban Design Standards*, the American Planning Association (APA) describes visualization as “the process for taking abstract ideas or data and translating them into easily understood and interpreted images to enhance planning, urban design, and decision-making processes” (APA 2006, 543). While the benefit of visualization in promoting engagement and facilitating effective communication has always existed, visualization tools and techniques are experiencing a digital renaissance. By the mid-1990s, Richard Levy had already identified the visualization value of advances in computer graphics for 3D urban modeling, but much was still promised to come (Levy 1995). With the merits of 3D visualization now treated as self-evident, it is common to see visualization marketed as an integral part of community consultation. Many consulting companies, such as IBI Group, advertise how they use 3D visualization to transform the delivery of technical information which allows citizens to “participate in meaningful decision-making, resulting in community buy-in” (IBI Group 2014).

While such language is used to make services easier to sell, the potentially negative connotations of ‘buy-in’ are balanced by a greater ability to accurately illustrate to citizens the factors which affect key decisions. Consequentially, as planners gain the ability to present robust alternative future scenarios, there will be an increasing demand for these new digital forms of visualization which help make data easier to understand, and which facilitate “real-time explorations of the relationships between social, environmental, economic, and land-use data, and built form proposals” (Kaliski 2009, 249). Given the expectation that resources and planners are likely to be stretched as a greater number of citizens begin to engage and public input grows (Ibid.), there is an increasing need to prepare planners to take advantage of VR technology and other advances in computer-based public participation. In this regard, it is particularly important to address the issue of representation: what reasonable expectations can citizens form on the basis of materials they are shown?

Representation and visualization in computer-based public participation

While the potential for visualization in computer-based public participation has been recognized for some time in planning, early explorations have often been plagued by the cost in time and money of tackling the issue of realism in representation. A common example can be found in a conference paper from 2004, where O'Coill and Doughty debate the merits of computer game technology for participatory design. After describing the paucity of study results on the topic, they detail their own experience with a research project using a game development package as a participatory visualization tool for residents in Hull, UK, who were being consulted on a design proposal for their neighbourhood (O'Coill and Doughty 2004). While O'Coill and Doughty recognized the potential benefits of real-time visualization and noted that the 3D modeling did, in fact, facilitate communication with regards to many points of the design on which residents were confused, their ultimate conclusion was that the cost and complexity of creating virtual environments precluded them from being worth it for most projects.

Figure 11, A view of the 3D visualization used by O'Coill and Doughty in Hull, UK.
[Source: "Computer game technology as a tool for participatory design" (O'Coill and Doughty 2004)]

Unsurprisingly, while most adults were reluctant to engage directly with the virtual environment and preferred to have the researchers demonstrate tours for them, children and those below thirty years of age had no hesitation about interacting directly with the modeled environment. Furthermore, some participants were confused by the fact that the virtual environment was not an exact replica. Due to the high costs in time and money of modeling every home in one-to-one detail, such efforts had been abandoned in favour of a representative built form which did not capture all the smaller architectural details of individual homes. O'Coill and Doughty note that it is the expectation of exact replication which also handicaps architects working on large modeling projects. They point to the case of an architectural firm hiring external game designers to provide more conceptually representative models, as being a contradiction to the idea that such modeling is accessible to all planners or architects in their professional practices.

Representation as the normal result of information abstraction

While the time-consuming necessity of the exact replication of reality in VR environments sounds intuitive, Whyte observes that the pursuit of realism can be deceptive and is even unnecessary (Whyte 2002). The abstraction of information into discrete and manageable chunks is a fundamental part of how our brains work (Stellingwerff 2005). However, even though experts may be better at ‘chunk’-ing, the relationship between objects in reality and our mental conception of those objects can never be assumed to be one-to-one (Whyte 2002). Rather, as with Kevin Lynch’s work on mental maps (Lynch 1960), even in our regular day-to-day experience of reality we subconsciously pick and choose what information (visual, or otherwise) we consider to be important.

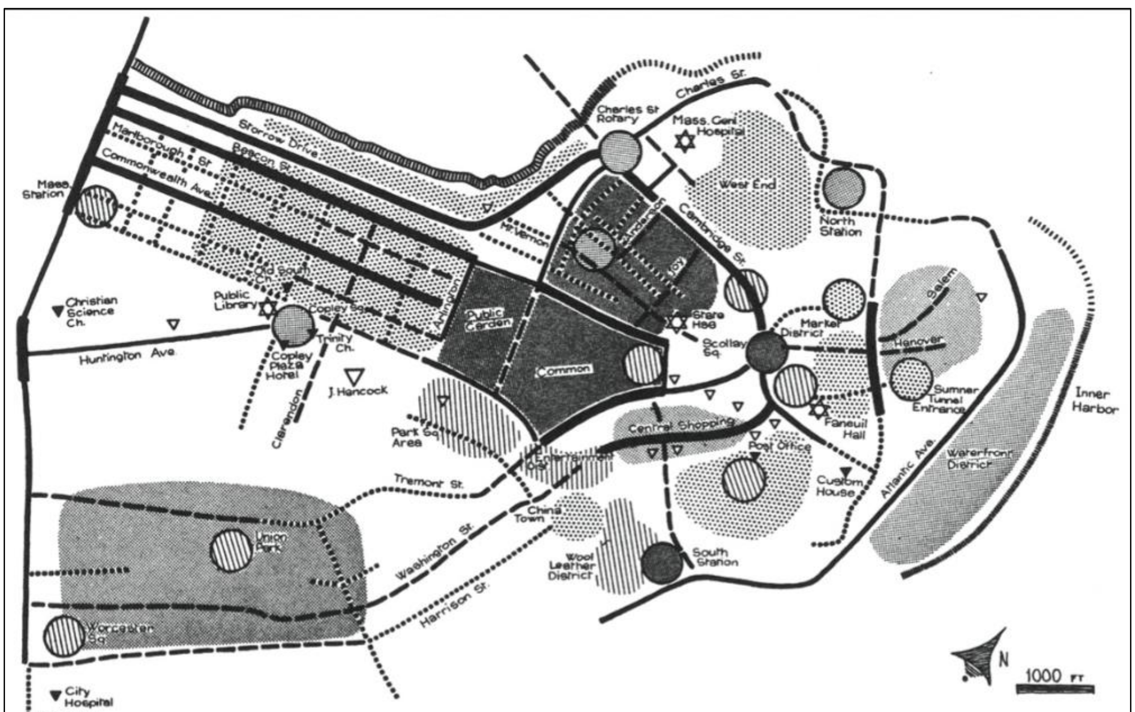

FIG. 35. *The Boston image as derived from verbal interviews*

Figure 12, A map of Boston created from the verbal descriptions of interviewees.
[Source: *The Image of the City* (Lynch 1960)]

As Whyte observes, if we use VR to try and build an exact replica of reality we are perhaps missing the point (Whyte 2002). While exactness has an important place in VR applications that require precision (e.g. engineers identifying errors between drawings, models, and existing infrastructure (Whyte 2002)), at other times – as with O'Coill and Doughty's older participants in Hull, UK – an exact and static replication can impede creativity; people may feel that a design is already set and that they are powerless to change it. Instead, as we approach potential applications of VR in planning, we should be open to the opportunity they provide to explore our context in a new way.

Imagination: envisioning what could be and what has been

As we age, some of us relegate imagination to the treasure trove of childhood innocence. We make remarks about the vivid imaginations of children unfettered by conventional bounds or cares: *if they actually knew how things really work, they would understand how that scenario could never actually happen*. Often we are correct; our own imaginations are generally tempered by experience and we are usually quite sure that our experience precludes certain scenarios from the realm of possibility.

Imagination, however, is a vital element for the architect, urban designer, or planner, who must confront the reality of an existing environment and – with an appropriate consideration for its historic context – envision a planned outcome which accounts for the complex interplay of inputs and outputs contained in the *problematique*, or wicked problem of adequately prioritizing the host of human needs and interactions. When we work with, and on behalf of, a diverse host of stakeholders, it is imperative to recognize that we cannot lay claim to having experienced everything that might be important in the context of our planning and design choices. VR can let us explore designs which are beyond the boundaries of what might normally be possible, or it can facilitate role play in a manner which supports empathetic education; it can allow us, for example, to experience the perspective of someone in a wheelchair and then to evaluate and consider how our planning choices might better promote universal accessibility.

The use of VR for visualization also has potential beyond envisioning future possibilities. The push for modernisation in Montréal, which saw major urban renewal projects such as the Ville-Marie expressway implemented in the wake of widespread demolition, was actually accompanied by an extensively documented inventory of the homes that were condemned (Ville de Montréal n.d.). VR visualization could offer citizens and students of history, the opportunity to revisit and explore the physical space of those old environments with a fidelity only limited by the historic documentation available. As exciting as it may be to consider VR's potential as a visualization tool for facilitating the communication of future scenarios, it is also worthwhile to reflect on how VR may offer us a better understanding of our historical context and a reminder of forgotten lessons. Although VR has quietly become commonplace, there are still incredible things for us to learn if we take advantage of its full potential to show us new ways of looking at our environment.

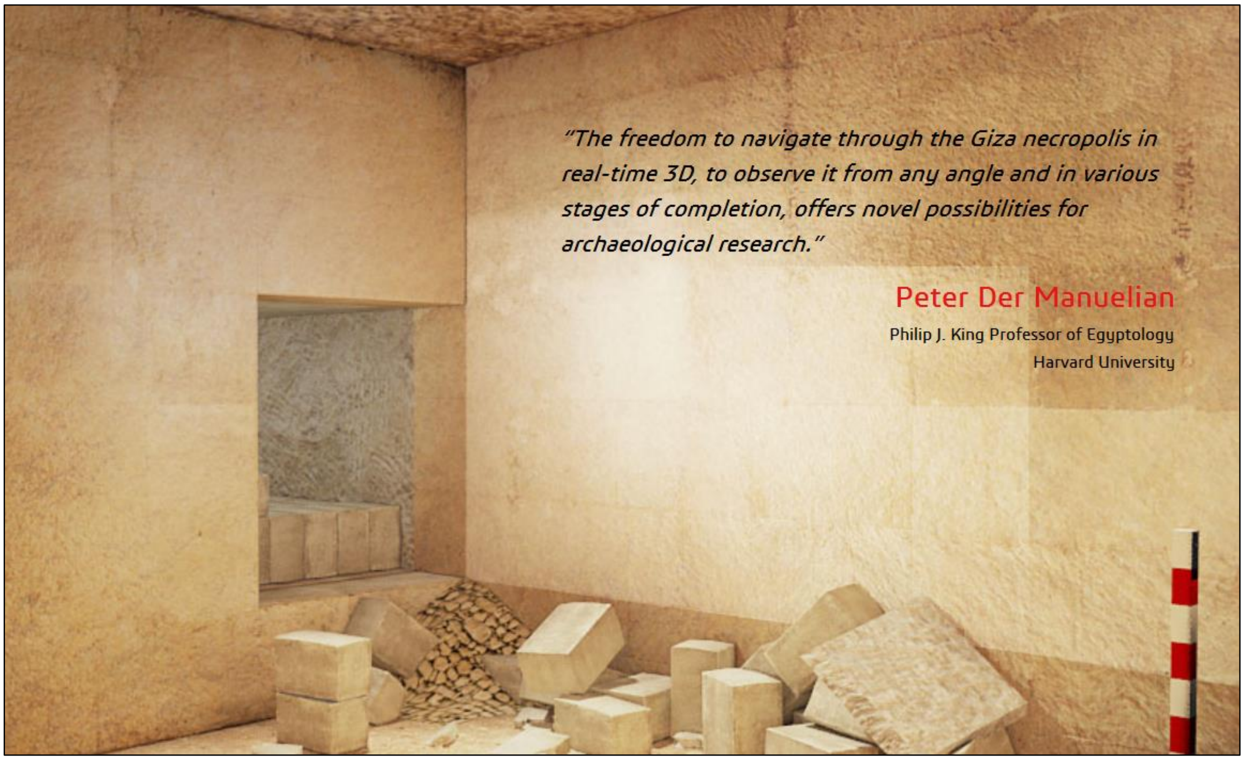

Figure 13, Giza 3D, a virtual model with a focus on historical accuracy.
[Source: "Giza 3D" (Dassault Systèmes; Harvard University; Museum of Fine Arts (MFA) Boston 2013)]

The ethics of visualization and the role of developers

With this new potential to better visualize what might be, there is also a greater need to ensure that there are no abuses of trust that may result from misrepresentation. Even when faced with only traditional 2D drawings and sketches for proposed development projects, communities and stakeholders are often concerned that the final development will differ from what has been promised or shown to them. Particularly with respect to marketing materials, there can be suspicions that appealing visualizations will not match reality; a rendering of a courtyard full of active people does not guarantee that the same space will be well trafficked when built.

Given concerns that developers and the business community may have more resources to dedicate to 3D modeling than municipalities who seek adequate control over the accuracy of designs and models, it may be helpful to consider how 3D visualizations can be included in the development review process. Cities like the Ville de Laval, which already has a requirement for developers to submit detailed files of 3D building models for design review, have an added advantage in collecting these models by gaining a digital record of the wider urban context as part of the regular review process (Edwards 2012). Developers may be hesitant to share their highly-detailed models with a wider audience and sometimes with legitimate reason, but there is definitely room for a conversation about visualization standards for virtual environments.

As observed by Levy, planners are not typically early adopters of technology (Levy 2014). As such, it seems likely that delays in realizing the full potential of virtual environments will also hold back efforts to establish standards for representation in planning practice. Here, however, it is helpful to consider the work of landscape architects who have already wrestled with the question of how virtual environments can be distributed and visualized in an ethical manner. Especially notable in this context, is the work of Stephen R. J. Sheppard who argued for a code of ethics to guide landscape visualization in virtual environments (Sheppard 2001).

Sheppard originally proposed five principles in 1989 that should serve as guidance for all manner of visualization: these were accuracy, representativeness, visual clarity, interest, and legitimacy (Sheppard 1989). While Sheppard's emphasis on accuracy and validity dates back to 1982 (Sheppard 1982), a central part of his more current guidance is a reminder that that the growing accessibility of visualization techniques means creators are less likely to be trained to consider how 3D visualizations may be misused (Sheppard 2001). The increasing prevalence of virtual reality environments that appear to be highly realistic can be problematic if an apparent realism is not supported by actual realism, or an acknowledgement of limitations in the representation of the underlying data (Sheppard 2009). As will be discussed in the next chapter, VR is becoming ubiquitous and the implications of that reality will require even more work on measuring and gauging the effectiveness of visualizations in planning practice.

Chapter 5: The advent of virtual reality as a ubiquitous medium

Before exploring the existing and potential uses of VR in planning, it helps to be familiar with some common issues that are raised when discussing VR as a medium. These sometimes controversial issues include not only questions of representation, as previously discussed, but also questions about how we use and relate to computer technology. For example: is there a limit to the adoption and use of VR beyond which we should not venture? New technologies often challenge traditional models and practices, and VR is no different. As with past technologies, the spread of VR will force society to wrestle with these questions because at the heart of such concerns is our basic desire to understand what it means to be human.

For many, the term *virtual reality* readily evokes imagery from science fiction films: the *Matrix* series (1999; 2003), *Inception* (2010), *The Lawnmower Man* (1992), *The Thirteenth Floor* (1999), *Strange Days* (1995), and so forth. Perhaps unsurprisingly, these movies are filled with ancient questions of epistemology and ontology, probing sources of knowledge and the very nature of being. What defines these films as science fiction though is that, in addition to these older philosophical conundrums, there is an exploration of humanity's relationships with science and technology: are these subservient, symbiotic, or dominant? Of course, the ultimate message of many of these explorations is that the result is both our choice and our responsibility.

With respect to VR, questions of the body – as viewed in scenes of people plugged into vats or with elaborate hardware systems worn on their heads as crowns, and/or with new powers at their fingertips – are not particularly new. An early use of the term 'virtual reality' can be found in the work of Antonin Artaud, one of the early pioneers of surrealism, whose treatment of the body would later be a focus of Jacques Derrida's early work collected in the 1967 *L'écriture et la difference* (Salter 2010, 46-47). In Artaud's 1932 text, "Le Théâtre alchimique," later spread in his seminal treatment, *The Theatre and its Double* (Artaud 1958), Artaud refers to theatre as *la réalité virtuelle* – the mirage of its props, characters, and principles, comparable to the transformative process of alchemical symbols turning base metal into gold (Weber 2004).

In many ways, VR offers a similar transformation: a virtual building can be an icon, representing the physical form of a real building, but it can also be a data-rich store of information on the building's energy inputs and outputs, its water use, or the historical records of its zoning. In construction management and facility operation, this is referred to as *Building Information Modeling* (BIM). Almost paradoxically, our experience of these information-rich environments can be both overwhelming and empowering. For example, consider the figure below of BIM at work in the design and construction of the Sutter Eden Medical Center in Castro Valley, California. Although the full display of this multitude of details testifies to the complexity of the coordination that BIM facilitated between hundreds of service and infrastructure elements, virtual models also offer the ability to layer information by toggling the visibility of pertinent information for different contexts (McGraw-Hill Construction 2009). An advocacy group concerned with accessibility could easily navigate such a model with an exclusive focus on elevator placement while other systems (e.g. electrical wiring or ventilation) could be temporarily hidden from view.

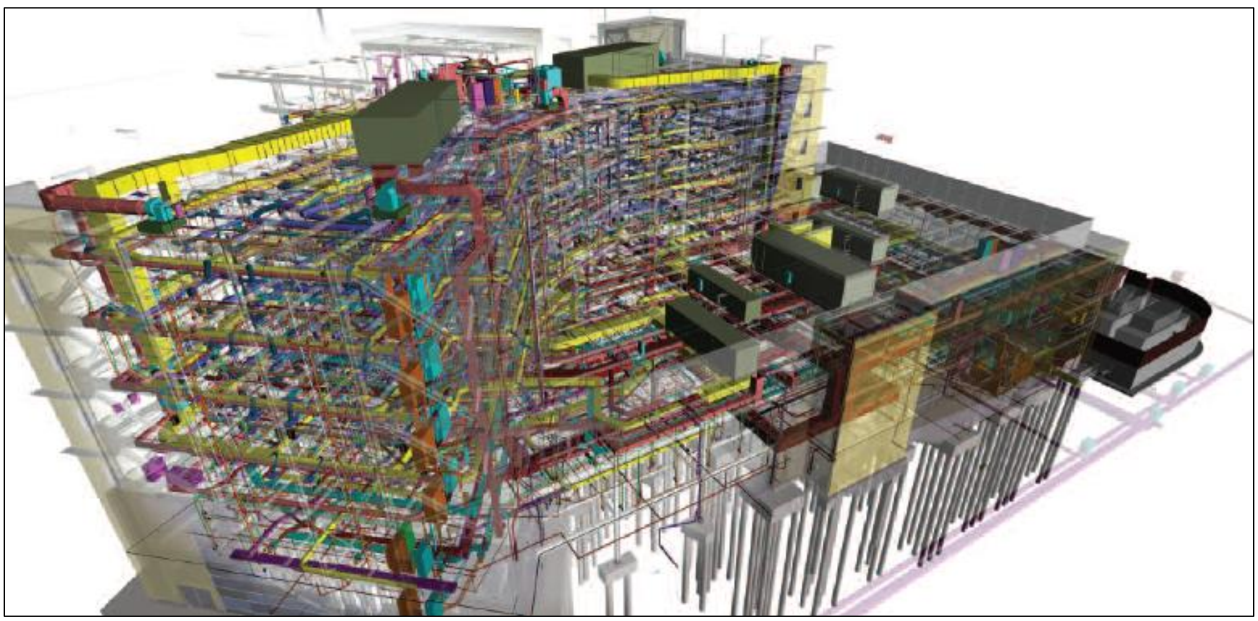

Figure 14, Building Information Modeling (BIM) for the Sutter Medical Center, Castro Valley, CA. [Source: Ghafari Associates (McGraw-Hill Construction 2009)]

VR and patterns of communication

Having likened the rich and transformative nature of virtual environments to the theatrical stage, our attention should turn to the creators of these scenes and the audiences who experience them. In some cases, such as participatory planning, the aforementioned advocacy group may have been invited from an early design stage to participate in elevator placement. In that context, the members of such a group could be both creators and audience. While Derrida's deconstructionist philosophy would come to challenge the very existence of unmediated reality, VR is implicitly mediated. The idea that we can never experience the same unfiltered reality may even favour VR. Whether or not the creators and the audience are the same entities, the comprehension of design intentions in a model is filtered through the lens of participants' experiences in the virtual environment. A true understanding of how we use and relate to VR as a medium involves both our communication patterns and the relation between our body and the VR system (the combination of hardware and software that create the experience).

Communication theorists use the term *computer-mediated communication* (CMC) systems to refer to the many new ways that computer technology affects how we both view and present ourselves. However, while CMC has become part of modern life, there is room for considerable research on how participants communicate in VR beyond the text-based CMC systems which we are only just beginning to understand. What CMC theories recognize is that, in addition to the interpersonal context of communication, our messages are also shaped by the type of technological systems we use to transmit them. In this particular regard we must acknowledge the merits of Marshall McLuhan's famous declaration that *the medium is the message*; the choice of a particular medium also conveys information. Today, a letter that arrives in the post, or an emoticon-filled SMS, can carry very different weights depending on the age of the audience. While we may not need to delve deeply into communications theory, planners must be prepared to face questions about the choice of VR as a medium and to explain how it is audience-appropriate, either in a general context, or as specific to different types of VR system.

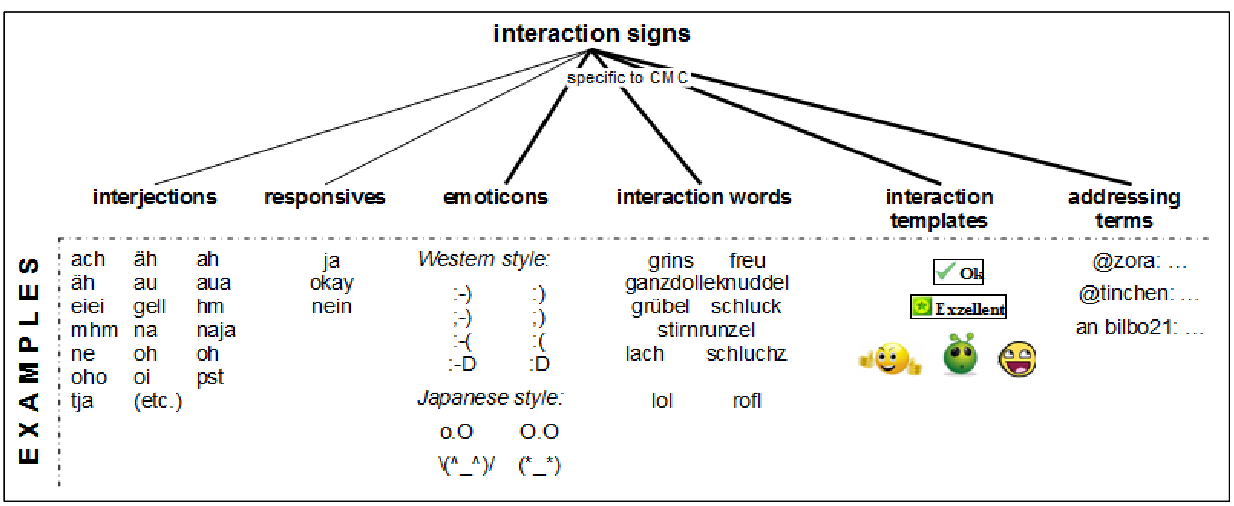

Figure 15, An example of a typology for interactions in German text-based CMC.
[Source: "A TEI Schema for the Representation of CMC" (Beißwenger, et al. 2012)]

As explained in the preface, the use of VR can be categorized by system type. These different types of system make use of a wide variety of input and output devices. Depending on the audience, certain input and output devices may already be familiar to participants, whereas others may require training or assistance to facilitate their use. To fully understand how public participants might communicate with VR, planners need to know how the choice of a particular VR system might affect both the overall process and individual experiences. What does it mean for planners if participants present themselves differently depending on their level of comfort with a chosen technology? In this regard, the study of human-computer interaction (HCI) can provide additional insight into how the spread of VR technology may affect public participants' expectations of CMC and their own experiences with the VR medium.

Human-Computer Interaction (HCI)

The evolution of research on HCI (human-computer interaction) has followed the development of several technologies which now form the basic foundation of how we use computers. From display functions which allowed the direct manipulation of graphical objects on a screen, to the input capabilities of the mouse, or the expansion of word processing, HCI research has explored how users can both affect and be affected by interactions with computers. Of these, the now ubiquitous nature of GUIs (graphical user interfaces) and the growth of the World Wide Web (WWW) are perhaps the most significant results of HCI research (Myers 1998).

As should be expected, these results of HCI research did not suddenly enter into the public's everyday experiences overnight. The historical timeline of HCI research clearly shows that university and corporate research often pre-date commercial products by decades. Furthermore, given the parallel nature and development of these technologies, it makes sense that breakthroughs and advances in one area contributed to research efforts in the others. In perhaps the most controversial case of such synergies reaching the commercial stage, Malcolm Gladwell and others have debated the mythology surrounding Steve Jobs' visit to Xerox PARC (Palo Alto Research Center) and the inspiration that PARC's mouse, GUI, and application windows provided for the Apple Macintosh (Gladwell 2011). Whether one believes that PARC failed by not commercializing its research, or that it succeeded by sharing its research with many in the name of innovation, it is clear that our modern computer experience would not exist without such early HCI research.

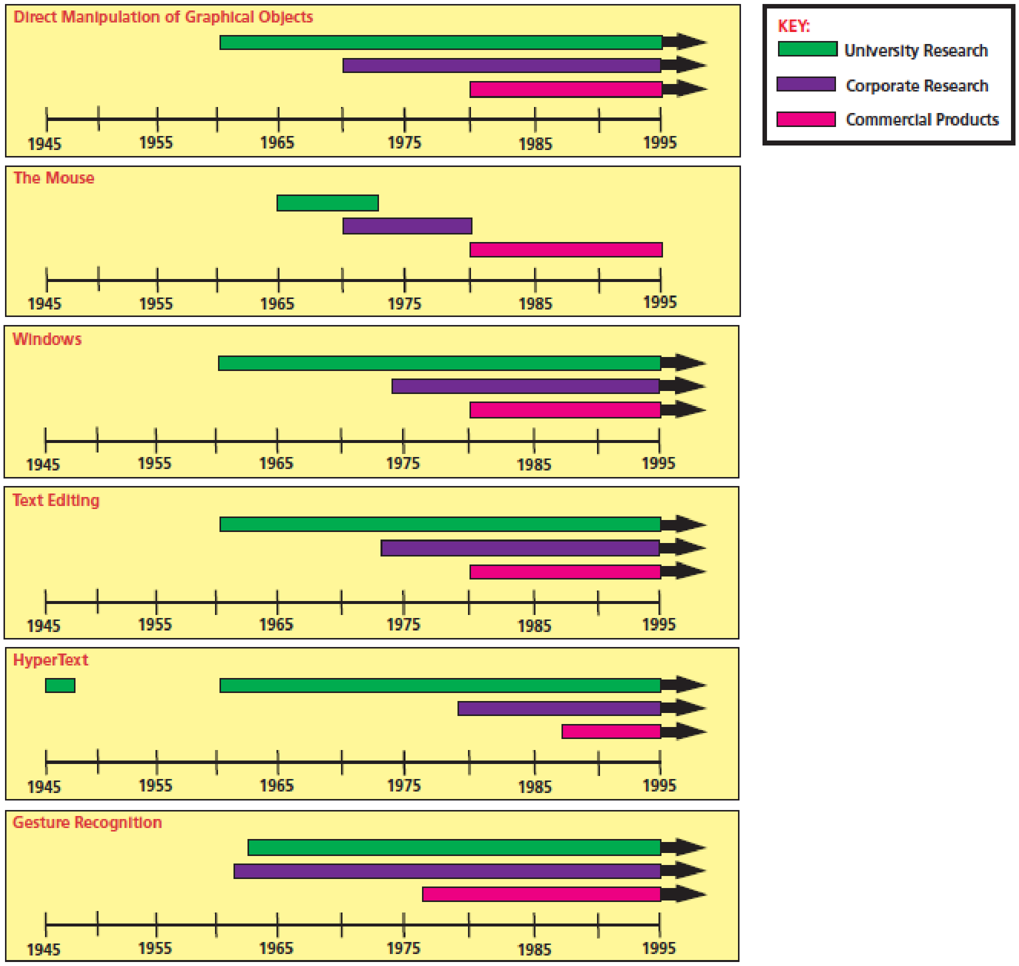

Figure 16, Approximate timelines of early developments in HCI.
[Source: "A Brief History of Human Computer Interaction Technology" (Myers 1998)]

While HCI was historically grounded in computer science with the occasional support of psychology, HCI research has become increasingly multidisciplinary and consequentially complex (Cairns and Cox 2008). Furthermore, as we try to understand the ways that we affect and are affected by our interactions with computers, HCI research is increasingly segmented by demographics (particularly with regard to age groups) on the basis of exposure to technology. Planners are already very familiar with the demographic transition to an older population that is happening worldwide (McCracken and Phillips 2005), but the challenge of socially dependable design for ageing populations is particularly relevant for HCI where unfamiliarity quickly trumps utility (Blythe, Monk and Doughty 2005, Goodman and Brewster 2005).

In the case of the medium of VR, the challenge of tailoring HCI research to fit common scenarios is further compounded by the critical fact that different types of VR system provide completely different experiences. This is primarily due to variations in the scope of our interactions with the respective categories of input and output devices that accompany each type. The simple features of non-immersive VR systems provide the easiest case for presenting VR as a ubiquitous medium but planners and the public need little introduction to the case for the use of 3D models. So many visualization opportunities related to the 3D modeling of urban environments that were astutely heralded in the mid-1990s are now taken for granted (Levy 1995).

VR system types, participant demographics, and HCI

Of the three types, non-immersive VR systems are the most accessible because many people are already comfortable using a controller, mouse, and/or keyboard as input devices and a computer monitor and speakers as output devices. In fact, active participation and navigation in this type of VR is almost guaranteed to be effortless for participants who are used to navigating in video or computer games. Although, such a statement might sound trivial, it is worth placing it in the context of media studies that suggest that children now spend more time playing video or computer games than they do watching television (Christakis, et al. 2004).

Planners who view even this basic type of VR as a barrier for older participants might be reluctant to consider using the other two types of VR systems, but it would be a mistake to ignore them. The pace of VR adoption and integration will likely scale with participants' ages but the technology does not have to be age-exclusive. While today's children will themselves eventually grow into retirees, planners can proactively contribute to introducing the existing older demographics to VR technology. Sensitizing and social learning are key practices in bridging the digital divide for seniors with regard to information and communication technology (ICT) (Männikkö-Barbutiu 2002). By giving seniors the opportunity to try new technology in a context where it is equally new for most other participants, planners can help to close the digital gap.

To put things in perspective, while older internet users were typically male in 2000, gender participation in seniors who use the internet has since equalized (Morgan 2005). Such changes are not simply the result of older cohorts passing on but include societal changes in family communication patterns and initiatives to provide shared learning experiences. Additionally, usability gains from HCI research spurred the evolutions in touch-based navigation that have made tablet devices such as the iPad very accessible and popular with seniors (Werner, Werner and Oberzaucher 2012).

While augmented-reality systems are arguably more complex than non-immersive systems due to their use of information-rich overlays blended with reality, the success of tablets in appealing to a wide age-range is a positive indicator of the potential reach for augmented reality. For many participants, the simplicity of touch-based navigation coupled with the familiarity of holding their device like a point-and-shoot camera makes tablets and smartphones easy to use as input devices. Likewise, the immediacy of the devices' output functions – in the form of displays with built-in speakers – may encourage a playfulness missing from a computer that is perceived to be part of a more formal setting. With non-immersive VR systems already being extensively used, it is likely that augmented reality systems will be the next type of VR to see widespread adoption.

Having made the case for the other two types of VR systems as frontrunners in ease of use and accessibility, it is necessary to explain why the eventual spread of immersive VR systems will be so ground-breaking and why planners should plan ahead. Although we have only discussed the visual aspect of VR as a medium, a VR experience can also be aural, haptic, and/or olfactory. In fact, it may even be gustatory (Ranasinghe, et al. 2013), although research on the electrical stimulation of the tongue has been more limited than that of other senses and receptors. While early versions of immersive systems were expensive, the experience of immersion was based on the novelty of spatial awareness rather than the comparatively low fidelity of the VR environments' graphical representations.

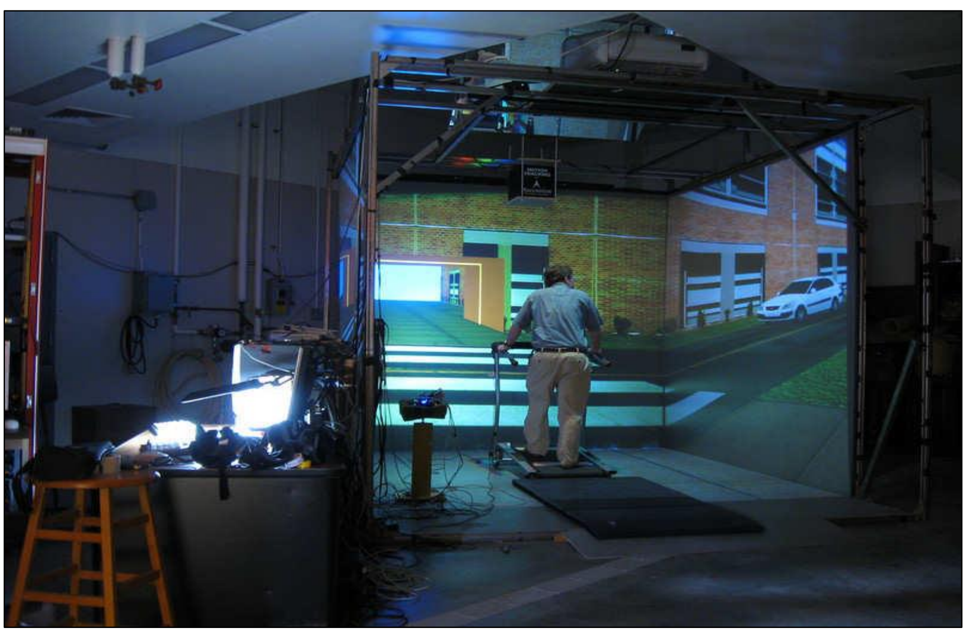

Figure 17, One of the first CAVEs, in operation and upgraded since 1995, at the University of Illinois. [Source: "CAVE" (Beckman Institute 2013)]

Whether in the form of custom-built rooms used as cave automatic virtual environment (CAVE) immersion systems, or speciality head-mounted displays, immersion systems had limited graphical resolutions in their output, and participant input was either managed through traditional interfaces or was non-existent (e.g. making use of pre-recorded/rendered paths and/or fly-bys). More expensive CAVEs also made use of audio and motors that could move the CAVE like an amusement park attraction but, as noted by O'Brien and Levy, it was often unclear if results suggesting heightened awareness were due to the immersion provided by the CAVE experience, or whether it was the novelty of the experience which captured participants' attention (O'Brien and Levy 2008).

The new advances in immersive VR systems which inspired this paper are based on earlier researched technologies but also introduce added dimensions to HCI research. The historical record will likely relegate the Oculus Rift to the status of an early precursor of consumer-grade immersive VR technology but the higher fidelity representation which it introduced has also brought challenges for HCI that are likely to persist for some time. As has been reported, the advent of the Rift was found in advances in smartphone technologies which drove small component prices down; this inexpensive assortment of miniaturized cameras, displays, and processors, led to a first prototype made from two phone displays (Downes 2014). The Rift hardware has since evolved into the early development kits now available to prospective developers but there are still many new unknowns: what are the medical effects associated with the extended use of an active-lighting high-resolution display that is centimeters away from a participant's eyes? Given the possible range of variations in participants' inter-pupillary distance (IPD), their individual sensitivity to issues of balance as governed by the vestibular system of their inner ear, or their unique responses to any head-tracking lag, will there ever be a quick standardized process for custom-tuning immersive VR systems to participants? Or will planners find the need for such customization to be an impossible barrier to the use of immersive systems for public participation?

While these issues are not insurmountable, they must be acknowledged and will no doubt be the subject of considerable research before they are solved. With Facebook's investment of $2 billion USD into Oculus, it is also probable that any advances Facebook makes will eventually be copied in other VR products. Even if these problems of personalization persist in hampering the shared-use of an immersive headset, many planners will still be likely to make use of immersive VR for visualization, if only for their own work. As the next chapter will explore, the opportunities provided have resulted in many new applications in other fields and industries whose value is inestimable.

A note on multi-user VR experiences

Whereas multi-user VR experiences in a traditional CAVE system consist of standing in and experiencing the same physical space, some have raised concerns that new VR systems will place greater limitation on multi-user experiences because they use head-mounted displays (HMD) (Levy 2014). As will be seen in the subsequent chapter, multi-user experiences are not a challenge for AR systems like Google Glass but it is true that fully immersive VR systems require additional work to integrate avatar representation in an effective manner to support natural conversation. Until now, virtual environments created for entertainment (such as in the games industry) have not adopted HMDs because of technological limitations rather than for any supposed incompatibility between HMDs and multi-user environments.

With the rise of the internet, the social element of games became incredibly popular in text-based MUDs (alternately, multi-user dungeons, dimensions, or domains) and MOOs (MUD, object-oriented). As these games evolved with the addition of graphical elements and with support for even greater numbers of concurrent users, they became MMOs or MMORPGs (massively multi-player online role playing game). These entertainment products already feature extensive avatar systems which allow users to portray themselves with varying degrees of realism and those opportunities are increasing. In response to the immersive Oculus Rift VR system, Sony and Samsung have both announced their own VR HMDs and it seems likely that multi-user VR experiences will become much more common.

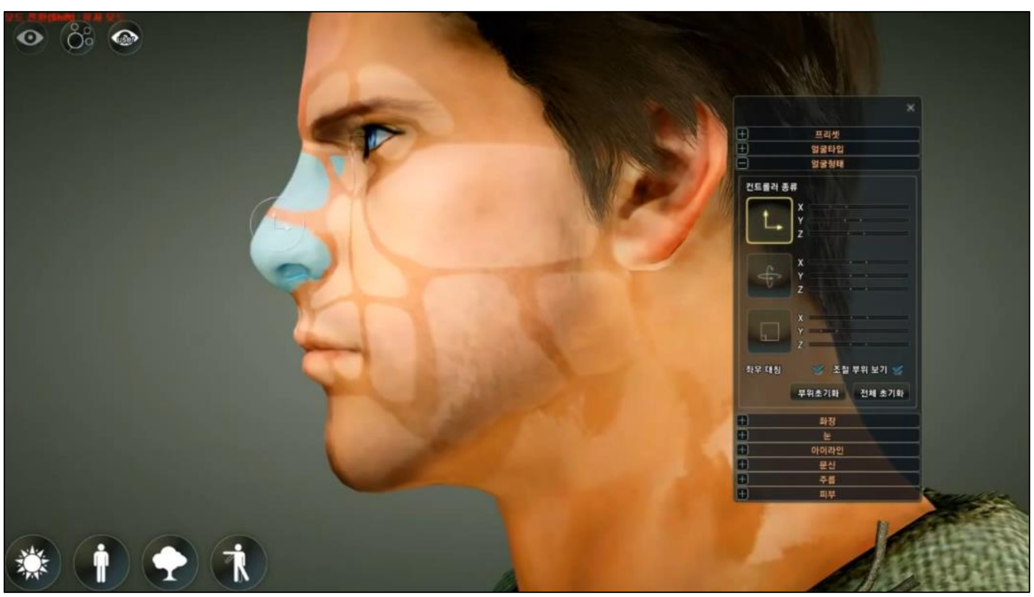

Figure 18, Avatar creation in a MMORPG with extra control of highlighted (blue/white) features. [Source: “Black Desert #CB2 Character Creation” (Black Desert Online 2014)]

Chapter 6: Reviewing contemporary VR systems and their applications

Although we have divided VR into three types of systems, charting the current trajectory of VR applications ultimately means exploring ongoing experiments and projects which are predominantly harnessing immersive VR. For all intents and purposes, non-immersive VR as defined in its original sense is already ubiquitous. Furthermore, despite including the original definition and typology of augmented reality systems, one can argue that advances in VR technology have highlighted the possibility that augmented reality systems are not really a separate type. Instead, it is possible that augmented reality systems exist as subsets of both immersive and non-immersive systems. Given that the underlying definition of augmented reality involves a blend of VR and reality, augmented reality systems might be better classified first by the type of VR of which they make use.

Understanding today's augmented reality systems

To explain this distinction, consider the details of how users navigate when using specific examples of current augmented reality systems. Given that VR is interactive, spatial, and real-time, per its defining characteristics, a focus on navigation allows us to break down where in a system the participants' experience of VR is happening. This is helpful for two reasons. First, the novelty of current systems can cloud our perception of whether the experience of VR is direct or indirect. Second, the relationship between navigation and the VR experience conveys information about whether VR or reality is dominant in the particular system. Consider these different examples of scenarios involving augmented reality:

Augmented Reality Scenario 1: Wayfinding

A user in the suburbs uses Google StreetView on a tablet to find a business they plan to visit downtown

- The system is non-immersive; VR does not fill the immediate periphery
- Virtual elements like directions and data (e.g. reviews) are layered over real elements
- Navigation is virtual; the user is distant from the physical location of any real elements
- Navigation is real-time but the reality aspect is static and indirect (captured panoramas)

Augmented Reality Scenario 2: Heritage

A tourist *in situ* holds up a tablet app to view a historical site as it was at some earlier point in history

Example: Streetmuseum app (Museum of London 2013)

- The system is non-immersive; VR does not fill the immediate periphery

- Virtual elements (e.g. reconstructed 3D models) can be combined with reality
- Navigation is real; virtual elements correspond directly with the physical environs
- Navigation is real-time and the reality is directly captured

Augmented Reality Scenario 3: Information Management

A doctor wears Google Glass in the emergency room to quickly consult data while talking to a patient

Example: Beth Israel Deaconess Medical Centre, Boston, MA (Ungerleider 2014)

- The system is quasi-immersive; VR can overlay most of the periphery of one eye
- Virtual elements like vital signs and data (e.g. drug dosages) are layered over reality
- Navigation is generally virtual and may even be indirect; voice commands or data pushed from other systems typically manipulate what is displayed in the overlay
- Navigation can be real (e.g. if turning to face physical *QR codes* for the camera to scan)
- Navigation is real-time but the VR context and the real context do not always correspond (e.g. consulting medical records virtually while looking at the floor)

Figure 19, Augmented reality at the Beth Israel Deaconess Medical Centre, Boston, MA.
[Source: “Who is already using Google Glass?” (Williams 2014)]

Augmented Reality Scenario 4: Collaborative Design

A process specialist uses a VR headset to consult remote colleagues about sightlines in a vehicle design

Example: Ford Motor Company’s FiVE (Ford's immersive Vehicle Environment) Lab (Carr 2014)

- The system is immersive; VR fills the immediate periphery

- Virtual elements like prototype vehicle designs are placed in real environments
- The navigation is real-time but the reality aspect is static and indirect (captured panoramas)
- The navigation is virtual; the user is distant from the physical location of any real elements

Figure 20, A process specialist and a display showing the view within Ford's immersive VR system. [Source: "Ford Taps Oculus Rift for Future Automobile Designs" (Carr 2014)]

These scenarios encompass only a limited selection of forms of augmented reality and they may have been hard to imagine in the past. This suggests that it will be important to formally revisit how we classify systems as VR development continues. In that regard, a deeper analysis could focus on the subdivision of tasks in each scenario to further identify where immersive and non-immersive systems differ when used independently or for augmented reality. Additionally, it is probable that the inevitable adoption of VR by a wider range of professionals will produce specialized configurations hitherto unseen.

To further complicate matters, it also seems possible for active participation in immersive and non-immersive VR systems to simultaneously coexist. These juxtapositions were also probably not foreseen because early hardware limitations would have made them sound like fantasy but it is now quite common to see incidents of this dual nature when immersive VR products like the Rift are being demonstrated for new users. This became evident when small proof-of-concept demonstrations would occasionally give rise to such situations when researching this paper: users seen having difficulty navigating (on an external monitor) could be assisted with an alternate set of input controllers.

The coexistence of immersive and non-immersive VR systems was typically revealed when participants who were unfamiliar with immersive navigation became stuck in the environment and signaled their need for assistance. In a dual-display setup, such as the one used in the research for this paper, the immersive stereoscopic view which the participant experiences is also displayed on a separate monitor. An alternate view is presented on the monitor by evenly splitting the display to show what each individual eye can see. As such, while the participant controls their own input in the immersive system, it is possible to separately take control of additional input devices in the non-immersive context to help guide the participant around any obstacles that pose a particular challenge.

With respect to social learning, these experiences also hint at the possibility that immersive VR may allow for more social interaction than one might initially suspect. This should not be surprising given that there is an extensive body of literature on social interactions in virtual communities such as *Second Life,* or online game worlds like *World of Warcraft*, although the direct relation with non-immersive VR systems is rarely consciously made. As demonstrated by the design teams at Ford who collaborate through immersive VR, or the doctors at Beth Israel Deaconess Medical Centre who can remotely accompany each other using Google Glass, the social potential of immersive VR and telepresence is likely to be greater than has been expected.

The growing adoption of immersive VR

Today, immersive VR systems are found in diverse environments with uses ranging from medical to manufacturing applications. At the University of Southern California's Institute for Creative Technologies (USCICT), the immersive Rift system has been integrated into the Institute's Virtual Iraq/Afghanistan PTSD (Post-Traumatic Stress Disorder) Exposure Therapy System (USCICT 2013). As part of the therapy, immersive clinical VR is used to recreate scenarios such as an improvised explosive device (IED) attack (Rizzo, et al. 2013). In an example of medical VR research, immersive VR is also being used to build on efforts dating from the 1960s to simulate a standardized patient for role-play in medical training and education. To that end, considerable attention has been given to simulating virtual patients in interactive patient scenarios (IPS) (Talbot, et al. 2012). Together with other examples of immersive VR applications, including clinically proven pain reduction in burn victims (Hoffman, et al. 2008), there is an increasing appreciation of immersive VR applications in the field of medicine.

Meanwhile, for fields and industries which already use non-immersive VR extensively in the forms of CAD and other 3D modeling, the adoption of immersive VR can be presented as a natural progression in established practices. Construction and manufacturing are prime examples of industries which already benefit from VR for prototyping and comprehensive design review. Building information modeling (BIM) in particular, as mentioned in the case of the Sutter Eden Medical Center, exemplifies the use of VR in project management for large and/or complex projects. Although such applications have been touted since the mid-1990s as a means to avoid misinterpretations between designers and clients (Gardiner and Ritchie 1999), recent technological developments have resulted in more widespread adoption of these practices.

Figure 21, Elon Musk demonstrating gesture-based immersive VR prototyping.
[Source: "The Future of Design" (SpaceX 2013)]

As referenced in the augmented reality scenarios, the Ford Motor Company uses immersive VR for prototyping and design in its FiVE (Ford's immersive Vehicle Environment) Lab. In a custom Rift setup that integrates motion-capture technology with a virtual automobile fully modeled in CAD, Ford engineers carefully track subjects in the virtual space as they collaborate in real-time from distant locations around the world to share design decisions and insights (Carr 2014). Other significant experiments in immersive VR applications for manufacturing include the work of Elon Musk, the business magnate and inventor behind the electric vehicle company, Tesla Motors, and the private space transport company, SpaceX. Using the Oculus Rift, Leap Motion (hands-free) controllers, and 3D printing, it is possible for Musk and SpaceX to 'rapid prototype' designs turning them into test parts on demand (SpaceX 2013).

Immersive VR and telepresence

Elsewhere in the aerospace industry, immersive VR is also being used in the context of telepresence. Targeted at future robotic interfaces, government-funded development of VR is being undertaken by the Human Interfaces Group at the National Aeronautics and Space Administration's (NASA) Jet Propulsion Laboratory (JPL) (NASA 2013). With the use of the Rift and Microsoft's Kinect 2 sensor, the JPL has developed a demonstration interface that allows the user to remotely manipulate a robotic arm whose range of motion has been mapped to natural body movements (Lee 2013). Future applications could include additional development of the telepresence abilities which allow for remote operation from Earth of NASA's Robonaut 2 on the International Space Station (ISS) (NASA 2013).

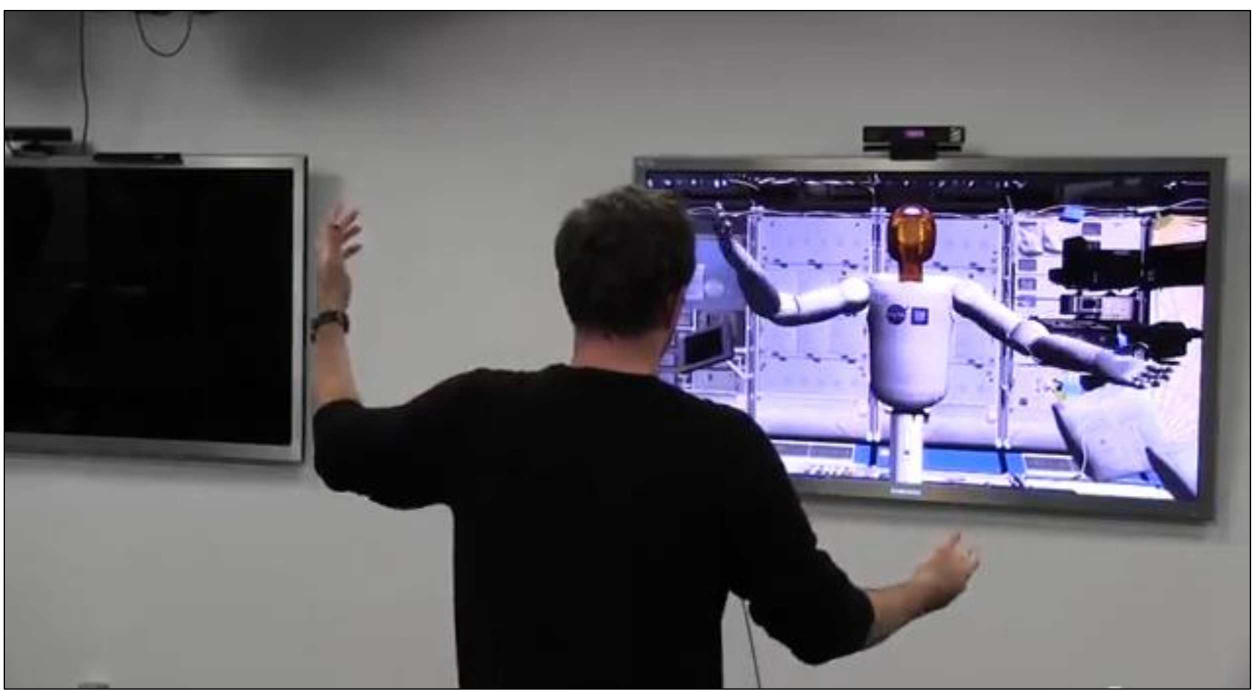

Figure 22, A mirror-mapped demonstration involving a virtual version of NASA's Robonaut 2.
[Source: "NASA Robot Arm Control with Kinect" (NASA 2013)]

In addition to applications in aerospace and robotics, the potential for *telepresence* is generally sought for education and training. For example, given that assembly is a major factor in the cost of constructing large structures, the use of VR for remote supervision or training can improve real world assembly efficiency and reduce related costs by allowing workers to practice and rehearse delicate installations (Gardiner and Ritchie 1999). As in the case of Beth Israel Deaconess Medical Centre in Boston, MA, *telepresence* can also allow less-experienced professionals (e.g. medical residents) to remotely follow and experience procedures for which they could not otherwise be present, or allow professionals (e.g. international specialists) with more experience to remotely assess scenarios and share their expertise with local practitioners.

Telepresence abilities are an important offering in VR systems and applications but there can be confusion about how the term *telepresence* is used. This quagmire results in part from early critiques of the term *virtual reality* which challenged (with some legitimacy) a hardware systems-based definition for the medium (Steuer 1992). In rejecting a systems-based definition, Steuer proposed a definition based on *presence* and, more specifically, *telepresence*. While acknowledging Marvin Minsky's creation of the term in relation to the teleoperation of physical objects through remote manipulation (Minsky 1980), Steuer coopted the term to focus on where an actor perceived their *presence* to be in a mediated environment (Steuer 1992).

This conflation of *presence* and *telepresence* seems particularly misguided in hindsight when one considers that Steuer also notes that Thomas Sheridan had previously distinguished, if not always consistently, between *presence* to refer to virtual environments and *telepresence* to refer to teleoperation (Sheridan 1992). In light of today's wide variety of VR contexts, that early separation in terminology appears apt while Steuer's research seems more in keeping with the relation between users and avatars. If *telepresence* is understood in relation to teleoperation, our definition is perhaps better expanded to encompass how other actors perceive our user. This may be more easily understood in the context of augmented reality where we can easily mix the possibility of both real and virtual avatars.

The abstraction in this scenario may seem superfluous but is necessary to capture the full range of contexts that we are beginning to see in VR applications. Despite trying to keep things simple, the nuances can be tricky. Imagine a hypothetical collaborative design consultation conducted over the internet by a heritage planner in Hong Kong, a research librarian at the British Museum in London, and a materials expert associated with UNESCO (United Nations Educational, Scientific and Cultural Organization) World Heritage in Paris. Tasked with restoring a historical asset in Hong Kong, the heritage planner wears an augmented reality device akin to Google Glass while on site.

While the planner broadcasts her view to the materials expert who is offering insights on finer details for further analysis, the librarian's expertise is not directly tied to the physical site and he is thus only receiving audio to help identify the possibility of finding aids for official records tied to the asset that might have been sent to the Foreign and Commonwealth Office during the colonial period. The librarian has a special GUI on his tablet and can share relevant documents directly with either or both of the other parties. The materials expert in Paris is using an immersive VR headset and has actually been given partial control of a small drone on site; her immediate context is a direct feed of what the drone sees but she also has a small video overlay so she can see also what the planner is looking at and she has an audio link with the librarian. In the planner's context, the materials expert's view appears in a video stream overlay in the corner of her field of view while the librarian is represented by a small profile photo as an avatar that blinks with each update to show documents that can be retrieved and enlarged in the planner's view.

With the basic scenario in place, let us now analyze presence and telepresence for these actors. In our construct, the librarian is the easiest actor to start with. Although he receives audio at a distance from both of the other actors, his perception of their *presence* is no different from when we use a telephone; it does not strictly encompass *telepresence*. As the materials expert only shares an audio link with the librarian, her perception of the librarian is similarly defined. In contrast, we will see that the planner's experience is slightly different. Finally, the librarian's perception of his own *presence* is very much within the immediate reality of his surroundings.

Our next subject is the materials expert. Being predominantly immersed in the context of the drone, her perceived place in the virtually mediated Hong Kong site defines her sense of *presence*. The materials expert's semi-autonomous control and operation of the drone, however, allows the planner to experience the material expert's *telepresence* in Hong Kong. However, as the planner interacts with the material expert's occupation of the physical avatar of the drone in Hong Kong and because the material expert's own perceived *presence* is in Hong Kong, the material expert experiences the planner's *presence* rather than *telepresence*.

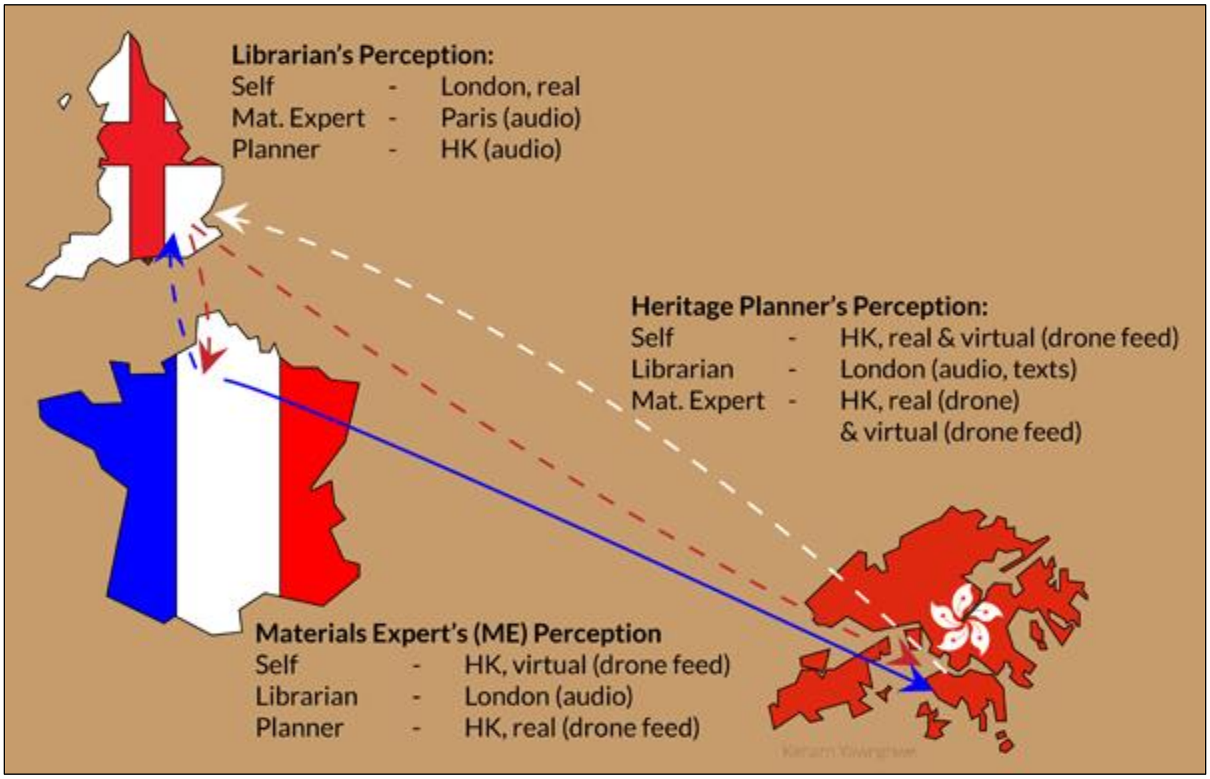

Figure 23, A diagram of actors' perceptions of presence (not to scale).
[Source: original content]

Finally, focusing on the most active viewpoint and one which requires our full attention, we turn to the planner's context. The planner's immediate context and thus perceived *presence* is reality but tempered by the virtual context of the augmented reality system's overlays. Due to the direct feed from the drone, predominantly controlled by the materials expert but which the planner can indirectly control by request to the materials expert or more directly through local means, the planner is actually also sharing the materials expert's immersive VR context non-immersively. Somewhat paradoxically, control of the physical avatar of the drone by the planner would be viewed as *telepresence* by a local bystander but as shared *presence* by the materials expert occupying the avatar of the drone; it would also be a separate *presence* for the planner from their temporarily-abandoned immediate *presence* in reality. While some might dispute the analysis, this lens of using *telepresence* as viewed by outside actors and qualified by a range of interactions with avatars would also mean that the planner is more likely to perceive the librarian's *presence* as being in London despite local representation in his avatar. If the librarian were able to more directly interact with the site in Hong Kong in such a manner that he or his avatar could respond meaningfully to the physical environs, the planner would then likely experience the librarian's *telepresence* in Hong Kong.

Some readers might challenge this assessment of the provided scenario but until there is a greater standardization in VR terminology and frameworks, there is a serious need for new proposals and refinements in the underlying theory. *Telepresence* abilities are only one facet of VR and there is still a lot of ground to cover in our attempts to better understand the implications and effect of the medium. As will be seen, *telepresence* can potentially provide significant opportunities to use VR applications for public participation in planning practice. With this in mind, we turn our attention to the next chapter and its discussion of the full potential which VR offers to planning practice.

Chapter 7: The potential of VR systems and applications for planning practice

Not unexpectedly, planners are well positioned to take advantage of recent advances in immersive VR. The current state of VR in planning is promising even if many planners do not consciously equate many common planning tools with VR. Regardless, the widespread use of such tools is testament to the utility of attributes inherent in these tools' qualities as VR systems. For example, few planners need an introduction to the visualization opportunities that can be provided by even the simple 3D models of a non-immersive VR system like SketchUp. Yet coincidentally, the suggestion of potential opportunities for VR applications in planning can elicit dubious reactions from planners. Previous efforts to actively promote tools which advertised that they innovatively harnessed VR never really took off, for legitimate reasons. The promised potential of these tools was often never fully realized due to technological limitations or unjustifiable expense.

These growing pains were inevitable and the reality of such disillusionment has been consistently addressed through the years including in fields, such as medicine, where greater funding exists for VR research (Rizzo 2002). In this regard, a debt is doubtlessly owed to those who have continued with their VR research for decades despite the naysayers. Additionally relevant to planners (as will be seen), there is also a growing awareness of the contribution of video and computer games in bridging the gap to realize the full potential of immersive VR (Stone 2009). In short, current advances in VR did not appear overnight; in order to understand the context and potential of VR adoption in planning, we turn now to typical examples of VR applications found in planning practice and the literature.

Non-immersive systems: the current state of VR use in planning practice

As readers are no doubt familiar with all of these systems, albeit probably not presented in the context of VR, the four selected examples are only briefly covered. While VRML is arguably the most deprecated, its status as an open format (free to use and implement) has made it a common vehicle for academic research on virtual reality as a visualization tool for planning practice. The inclusion of CommunityViz represents the context of community planning tools but is tied to the proprietary data formats of ArcGIS, a leading GIS software package from Esri (originally, Environmental Systems Research Institute). Trimble SketchUp is also proprietary but represents the lower-end of the full range of CAD and 3D-modeling packages used in planning practice. Finally, as one of the newest and more expensive visualization offerings available, Esri CityEngine is a 3D-modeling engine that can procedurally model city-sized models through its integration with GIS – namely, ArcGIS – and building information management (BIM) data. Applications of each of these four examples are common to planning practice and are typically non-immersive but would theoretically require only minimal adjustment to harness the potential of immersive VR systems.

Non-Immersive Tools Example 1: VRML (Virtual Reality Modeling Language)

VRML (Virtual Reality Modeling Language) – originally Virtual Reality Markup Language – was a standard developed in the 1990s to complement HyperText Markup Language (HTML). According to Tim Berners-Lee, who invented the internet and pioneered the use of Uniform Resource Locators (URLs), HTML, and the HyperText Transfer Protocol (HTTP), VRML was an effort to push the World Wide Web (WWW) in the direction of 3D and the widespread creation of virtual spaces (Berners-Lee 1995). At the First International WWW Conference at CERN (the European Organization for Nuclear Research) in Geneva, Switzerland in May 1994, Tim Berners-Lee and David Ragget (of Hewlett Packard) discussed the idea for a common language that could represent both 2D and simple 3D objects in 3D scenes. The resulting momentum was harnessed by Mark Pesce who championed the VRML name that Ragget had coined and organized the www-vrml mailing list to prepare a draft version of the specification to be adopted that autumn (Pesce 1995).

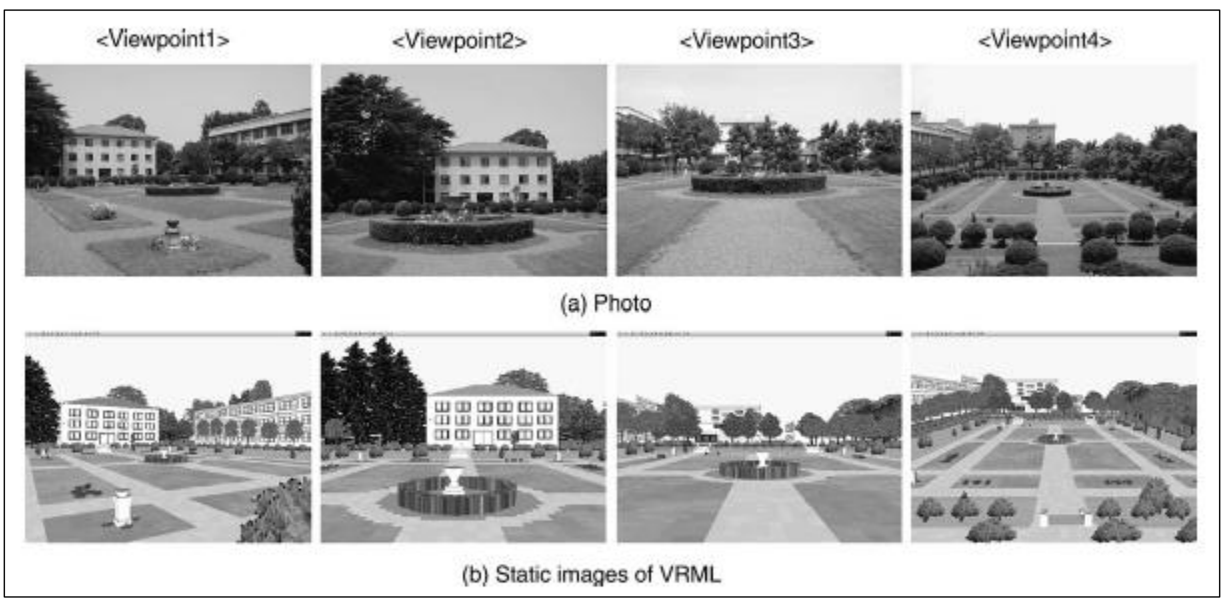

Figure 24, Photo references compared against similar views in a VRML environment.
[Source: "The validity of VRML images as a stimulus for landscape assessment" (Lima, Honjo and Umekia 2006)]

The fact that the initial incarnation of VRML only allowed for static 3D scenes (restricting the opportunity for interaction) has been attributed to the core design philosophy of VRML which prioritized making the specification an open format (Couch 1997). These limits on interaction changed in 1997 with VRML 2.0 (also referred to as VRML2, or VRML97) but VRML never really made headway in the mainstream market. Despite this fact, VRML was embraced as a relatively inexpensive way of presenting 3D environments. Though low in fidelity, VRML could also be used for immersive VR. While VRML appeared to disappear from the wider technological scene due to its inability to keep pace with real-time 3D solutions, research papers are still being written about VRML in the academic community.

Non-Immersive Tools Example 2: CommunityViz

The initiative to create CommunityViz (a decision support system for community planning) began in 1996 and was driven by the Orton Family Foundation, a non-profit organization local to Vermont. The aim was to help rural communities across the United States of America preserve the character of their traditional towns and villages in the face of growing development (Kwartler and Bernard 2001). Given the awareness that many small town planners in Vermont were volunteers without formal training, CommunityViz was meant to give citizen planners the tools necessary to help communities visualize and simulate policy changes that might affect their futures (Ibid).

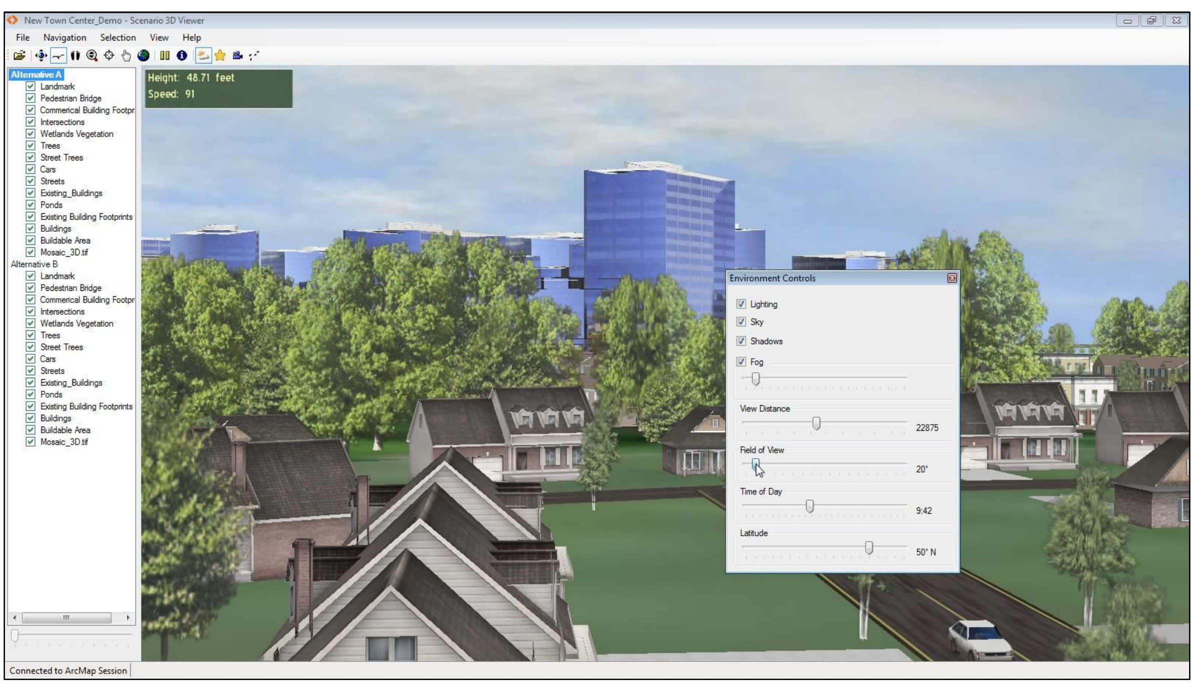

Figure 25, A frame from an instructional video on navigating scenes in CommunityViz's Scenario 3D. [Source: "Scenario 3D: Exploring a Scene" (CommunityViz 2013)]

CommunityViz was built as a set of extensions for ArcGIS and was a pioneer in integrating multi-agent simulation modeling and both 2D and 3D visualization with GIS (Ibid.). By early 2001, eight communities had tested CommunityViz and another twenty were scheduled to follow. Since then CommunityViz has largely been very successful and is often cited as a key visualization tool in participatory planning. Today, CommunityViz has evolved slightly from its original three modules (Scenario Constructor, TownBuilder 3D, and Policy Simulator) and is now comprised of two components: Scenario 360 and Scenario 3D. As evidence of the widespread use of CommunityViz in the USA, the American Planning Association (APA) published *The Planners Guide to CommunityViz* in 2011 (APA 2013).

Non-Immersive Tools Example 3: Trimble SketchUp

Today, SketchUp is very familiar to architects and planners, as well as to many professionals in a variety of fields who depend on computer assisted design (CAD) and 3D-modeling software for their work. As a basic modeling application that allows quick and easy 3D environment creation, SketchUp was widely marketed as a design tool for initial concept work (Digital Media Net 2002). First developed by @Last Software to provide access to 3D-modeling without the need for CAD expertise, it soon won a Best of Show award at the Macworld Conference & Expo in New York in July 2002 (Macworld 2002). SketchUp's success and the development of a plug-in which allowed SketchUp models to be geo-located using Google Earth (Donley 2011), led to Google's acquisition of @Last Software in 2006 (Daily Camera 2006).

Figure 26, A geo-located SketchUp model from one of the author's own studio team experiences.
[Source: "La Faubourg Gouin" (Francia, et al. 2012)]

Following the acquisition, Google restricted a few minor features of SketchUp to a professional version of the software but also released a free version with almost identical functionality (Donley 2011). In doing so, Google accomplished its intended result of seeing SketchUp receive wide adoption by both budget-minded professionals and amateur 3D-modellers. More recently in 2013, SketchUp was acquired by Trimble (a company known primarily for its positioning and navigation services) but still retains the ability to geo-locate models with Google Earth (Trimble 2013). SketchUp is now a staple of many planning school experiences and will no doubt continue to be used by many professionals as a quick and easy concept tool.

Non-Immersive Tools Example 4: Esri CityEngine

CityEngine was born from the research work of Yoav Parish and Pascal Müller, who presented "Procedural Modeling of Cities" at the ACM's (Association for Computing Machinery) SIGGRAPH (Special Interest Group on Computer Graphics and Interactive Techniques) 2001 conference (Parish and Müller 2001). Procedural modeling algorithms automatically turn sets of rules into computer graphics by generating models and applicable textures according to parameters and templates that are provided as input to the computer. Müller continued the research and founded Procedural, which developed CityEngine and which was acquired by Esri in 2011 (Esri 2011).

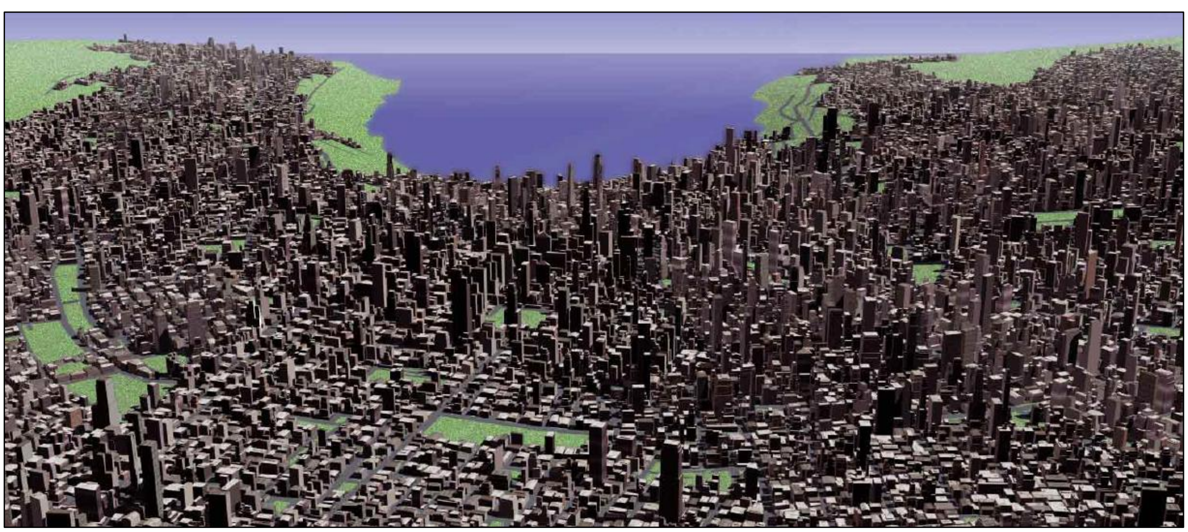

Figure 27, A virtual city of ~26,000 buildings procedurally modeled in the precursor to CityEngine.
[Source: "Procedural Modeling of Cities" (Parish and Müller 2001)]

Advertised by Esri as a way for municipalities to easily undertake important planning initiatives, CityEngine is integrated with ArcGIS to generate 3D models from a city's existing store of building footprints and other municipal data. As a result, CityEngine is presented as an effective visualization tool for city-scale changes in cities which do not already have a complete virtual model inventory of their building stock. While CityEngine is outside the reach of those with smaller budgets, planners should not be dazzled by the images that Esri is offering.

Strictly speaking, CityEngine's strengths are found in the layers not seen at first glance: its quick generation of 3D models, the integration of BIM and municipal databases, and its instant report generation. These are all important features for planning practice but, in the context of VR environments, they miss the mark for immersion at smaller scales where participants are more likely to question visuals generated from representative templates that do not actually match the details of building features in reality. For larger municipality that already make extensive use of ArcGIS, a single license for CityEngine may not be unreasonable but there is still plenty of room for other tools.

Figure 28, A visualization for Phosphore 2, a project that envisions Marseille in 2030 (Eifffage 2014).
[Source: "Marseille Urban Planning Project" (Esri 2014)]

As evidence that CityEngine is perhaps prized more for procedurally generating believable urban fabric, rather than portraying any real city, it should be noted that CityEngine has been used in both the recent Superman movie, *Man of Steel* (2013), and the remake of *Total Recall* (2012) to create the fictional cities which serve as backdrops (Failes 2013). Moving beyond procedurally generated cities and examples of VR applications in current planning practice and the literature, we turn to a perhaps unexpected source of relatively high fidelity urban modeling.

Urban modeling: real cities captured by the video and computer games industry

The game, *Watch Dogs*, a so-called 'triple A (AAA)' title designed to showcase a studio's expertise and innovation, is set in contemporary Chicago and is reported to have had a development budget in excess of 50 million Euros (over $69 million USD) even well before its delayed release on May 27, 2014 (Mosca 2013). Gamers increasingly demand immersion in their game experiences and, as seen below, considerable resources were clearly invested in replicating Chicago with relatively high fidelity.

Figure 29, East Upper Wacker Drive: (a) *Watch Dogs* above, and, (b) Google StreetView below.
[Sources: (a) "Watch Dogs Media Coverage" (rockman zx 2014), (b) (Google n.d.)]

Although it is relatively easy to only model major landmarks in games, game industry titans have striven to perfect realism in computer graphics for many decades and at great expense. While we have already discussed the potential dangers of exact replication in VR, it is evident that photorealism can contribute greatly to immersion if content creators are able to spare no expense. Given that game developers are consistently innovating in this regard, they have a considerable lead in urban modeling even when compared to CityEngine, where the functional-realism of procedurally generated cityscapes is primarily found in the general form of the urban fabric and easily recognizable patterns of the street grid.

Figure 30, Comparison shots of Pantages Theater. [Source: "L.A. Noire Hollywoodland Tour Guide Now-And-Then" (VampireHorde2 2011)]

L.A. Noire (2011), which broke medium barriers as a selection of the Tribeca Film Festival, famously recreated an incredible approximation of 1940s Los Angeles (Stoudt 2011). Using Works Progress Administration maps, U.S. Geological Survey topographical data, and the *Spence Air Photos, Inc.* collection at the University of California, Los Angeles (M. Stone 2011), Team Bondi brought *L.A. Noire* to life in a manner that was critically acclaimed and which saw particularly dedicated gamers photographing locations in real life to provide comparison shots. Although the Spence collection, which features extensive oblique aerial coverage of the city between 1918 and 1971 in the form of 130,000 photos, sees regular use by a wide variety of researchers, it is interesting that it took a game to share Spence's informal record of urban development with the larger public.

Other examples of notable games which have featured recreations of real cities or neighbourhoods include: rough approximations of Miami, San Francisco, Los Angeles, and New York in *Driver* (1999); central London in *The Getaway* (2002); Los Angeles in *True Crime: Streets of LA* (2003); Tokyo's Shinjuku ward and further afield in the *Yakuza* series (2005, 2006, 2009, 2010, and 2012); Hong Kong in *Sleeping Dogs* (2012); and Seattle in *inFAMOUS Second Son* (2014). As one might expect, the accuracy of these recreations has increased chronologically in pace with technological advances in graphics hardware and computing power. While visuals and graphics are only one part of a game experience, they are seen as incredibly necessary to capture the atmosphere and setting in which designers wish to immerse players.

Currently, in Montreal, a game development studio called Pixyul has recently announced its work on *ReRoll*, which promises a geographically accurate Montréal (Tach 2014). Pixyul's efforts to digitally recreate Montréal are apparently being produced in partnership with Géomatique Montréal, the city's geomatics division (Pixyul 2014), and the official *ReRoll* forums detail plans to map physical locations around the world with drone technology (Max3dmoon 2014). While ambitious games that are still in development typically risk remaining unfinished and becoming known as 'vapourware,' it is interesting that the Ville de Montréal is apparently interested enough in such initiatives that it is willing to share its geospatial data.

Figure 31, A virtual Montréal recreated from city data for *ReRoll*.
[Source: "ReROLL Brick1 Announcement" (ReROLL Community 2014)]

Furthermore, if such data-sharing partnerships are available to private game developers, it seems reasonable to suggest that an even greater potential for VR planning applications could be found in open data arrangements with the public. Returning to the spectrum of public participation and the value of social learning, if municipalities can re-evaluate how they work with citizens in ways that: 1) involve the public; 2) allow for collaboration; or 3) empower the public; those same municipalities have the potential to accomplish much greater things than they might otherwise expect. If a computer game like *ReRoll*, or various alternate reality games (ARG: a type of role-play game which make use of real world elements), can excite people by simply offering the satisfaction of crowdsourcing the solution to problems that are bigger than any one individual, then cities have so much more to offer to citizens who possibly feel disenfranchised and impotent with regard to civic affairs.

Similar ideas have already begun to be tested in Germany. Using *playful public participation* (PPP), an initiative at the University of Hamburg created a public participatory game called NextCampus which examined the question of a possible relocation of the campus by the university (Poplin 2012). While key critiques included the suggestion that the game might be too complex, that the results might not be taken seriously, that it was difficult to validate or quantify the possible consequences of different choices, and that a full implementation might be costly, participants welcomed the approach. Interest fuelled the motivation to participate and, while not quantitatively tested, test subjects described a sense of joy and playfulness in participating.

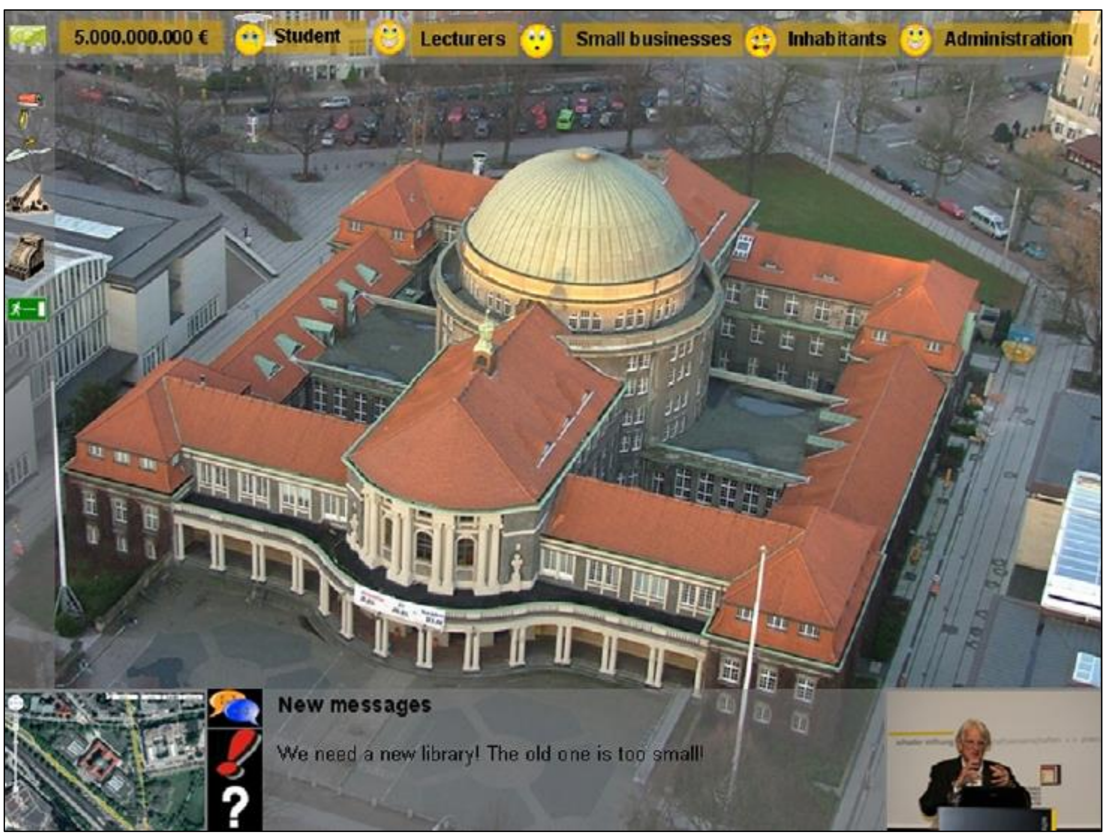

Figure 32, Designing the user interface for the University of Hamburg's NextCampus game.
[Source: "Playful public participation in urban planning: A case study for online serious games" (Poplin 2012)]

Immersive VR systems: tapping the potential for public participation in planning

As the old saying goes, a picture is worth a thousand words. As discussed in Chapter Four and evidenced in much of planning practice, the merits of visualization tools for public participation in planning practice are widely recognized (U.S. Department of Transportation 2011, Center for Interactive Research on Sustainability 2013). While 3D visualizations are only one type of visualization tool, technological advances have greatly increased their value in communicating both problems and potential solutions (Cirulis and Brigmanis 2013). Furthermore, these benefits have been observed by planners around the world.

From aiding in the creation of a plan for the island of Koh Mudsum in Thailand, where 3D visualization helped participants to be meaningfully involved in discussing site conditions, challenges, and alternatives (Wanarata and Nuanwan 2013), to being effectively used in participatory landscape planning workshops for the Entlebuch UNESCO Biosphere Reserve in Switzerland (Hayek 2011), 3D visualization is understood to play an important role in various stages of the planning process. With the necessary caveats about representation previously discussed, good 3D visualizations can provide highly identifiable environments which participants can intuitively navigate and relate to as a backdrop for their discussions of local opportunities and challenges. As the digital assets of these 3D visualizations can be transferred from traditional non-immersive VR systems to newer immersive VR systems, the case that remains to be made is why such a move should be made. What makes immersive VR different?

First and foremost, it should be noted that planners' familiarity with 3D visualization and computer assisted design (CAD) represents a relatively low barrier to entry for such a transition. Furthermore, while immersive VR systems were once relegated to the realm of expensive custom systems, all of which were relatively immobile, immersive VR is now relatively affordable and can be as portable as a pair of glasses, or a lightweight headset with a small wearable battery. As the continued miniaturization of technology – with nanotechnology rightly, or wrongly, being the holy grail of such development – has long been a given, it is now possible to use these systems and tools directly on site.

While there may still be specialty applications for the purpose-built rooms, large curved screens, bodysuits and/or head-mounted displays of the past (Gardiner and Ritchie 1999), the public will be far removed from the context of the famous joke that sets the stage for Douglas Adam's comedic science fiction series, *The Hitchhiker's Guide to the Galaxy*. Whereas the protagonist Arthur Dent awakes to the imminent destruction of his home, the result of having missed the window of opportunity to contest development plans on display in the local planning office for the past nine months (in the unlit cellar "on display in the bottom of a locked filing cabinet stuck in a disused lavatory with a sign on the door saying *Beware of the Leopard*") (Adams 1979, 12), portable immersive VR could allow participants to walk around their neighbourhood at any time and see it both as it exists and with any proposed changes.

Figure 33, Planning notice scene in the 2005 film version of *The Hitchhiker's Guide to the Galaxy*.
[Source: *The Hitchhiker's Guide to the Galaxy* (Adams and Kirkpatrick 2005)]

While it was this scenario (helping concerned local stakeholders envision how infill development could integrate harmoniously in the existing urban fabric) that inspired the research for this paper, there are many other opportunities to evaluate how immersive VR can answer challenges in planning practice in innovative ways. Among these, we will examine two scenarios: 1) how immersive VR can contribute to universal accessibility planning; and 2) how immersive VR can offer greater opportunities to experience comparative case studies firsthand with virtual site visits to remote (and even international) locations. While neither of these may appear to relate specifically to public participation, the very essence of their value in this regard is that if planners and the public are able to share these same experiences, they will share a richer common vocabulary of ideas and experiences with which to work together.

Immersive VR Scenario 1: Universal Design and Accessibility Planning

Universal design is a design philosophy that seeks the widest possible range of usability, rather than categorizing people by specific needs to emphasize adaptation or specialized design. Instead of focusing on ability or age, it proposes that there are solutions which are simply better for everyone, regardless of their situation or stage of life. While one might eagerly endorse universal design, it is still very possible to fail to envision the full extent to which one's own experience of space might bias design decisions.

One of the great advantages of immersive VR is that it is possible to offer participants a realistic experience of an environment while also allowing that experience to be altered in real time through variable parameters (e.g. seasonal variations, day and night cycles, or tree growth over several decades). In the same way that immersive VR participants can virtually move through time and see what their street might look like in twenty years, it is also possible to alter their physical viewpoint; a participant whose height is 145cm can experience what it is like to have a height of 180cm (minus actually hitting his head on a low ceiling, unless some extreme future simulation is designed to also provide that physical feedback). In a multi-participant VR environment, it is also possible for participants to take on different forms, or avatars, rendering age or gender meaningless in the same manner that universal design strives to exemplify. By offering the opportunity for participants to experience spatial and social interactions in a new way, immersive VR provides much greater opportunities for educative role-play that can challenge our own bias.

Figure 34, An example of a case where universal design would help everyone.
[Source: "Strollers, seniors, shopping carts & kids - but no curb ramps" (Brayj 2014), License: CC BY 2.0]

Given the potential of this learning context of VR, immersive VR offers accessibility planners the chance to experience a planning site in a myriad of ways that they might never have considered. Furthermore, if we acknowledging the role that empathy can play in education (Feshbach and Feshbach 2009), it is also likely that if participants are presented with the chance to experience a site from the perspective of various other stakeholders, they will have a much greater opportunity to understand these other contexts and thus contribute to meaningful discussions about possible solutions. Given that good planning practice is ultimately about a spirit of cooperation and collaboration, immersive VR as used in this scenario promises opportunities which may be harder to grasp in more traditional practices.

Immersive VR Scenario 2: Remote Presence in Comparative Case Studies

While purely anecdotal, relative to the general population, planners seem to have a great propensity for traveling to other cities and taking considerable amounts of photos of the urban form. Although the behaviour is possibly worthy of study itself, the phenomenon likely results from the profession's continual quest for examples of innovation and/or best practice. Given our patterns of settlement and urbanization, there are actually relatively few urban centres when compared to the total area of the earth. Although the value of comparative case studies and best practices is tempered by cultural differences, the truth concerning most large-scale planning initiatives is that larger urban areas already have considerably fewer opportunities for any comparison as their populations scale upwards. According to the 2011 revision of the United Nation's "World Urbanization Prospects," there are only about thirty urban agglomerations that have a population of 9 million or more, and only about five or six with a population of 20 million or more (United Nations 2012).

Regardless of size, when opportunities to showcase particularly good examples of planning practice do arise, a corresponding challenge is that these cases are actually liable to be quite far from the communities in which planners are working. If it is already somewhat inconceivable that professional planners would be able to travel to these sites at their leisure, it is completely without reason to suppose that every member of the public will also be able to do the same. Of course, as alluded to earlier in the hypothetical scenario of the heritage planner in Hong Kong, immersive VR has the potential to eliminate distance. While the implications of that statement carry far-reaching impacts beyond the context of this scenario, it is not far-fetched to suggest that, as virtual versions of accurately-modeled cities become common place, public participants will be able to experience for themselves what works and does not work in cases which are shared with them as examples of alternate visions of development. Furthermore, given that long distance travel has typically been a luxury, this feature of immersive VR is also one which promotes social equity.

Within the context of public education, an important quality of remote presence in immersive VR is that it also encompasses the ability for planners to broadcast, or ‘stream,’ a tour of a site across the internet to a much wider audience. In 2007, among the wider community engagement initiatives undertaken during Jennifer Keesmaat’s (currently Chief Planner for Toronto) work on the strategic plan “Our Future Mississauga,” ‘Fresh Eyes’ tours were conducted as a way for city staff, advisors, and the consulting team to meet community members and learn firsthand about key issues and visions for the future (City of Mississauga 2008). While some contexts might prevent such openness and transparency, the use of immersive VR in such a case would have potentially allowed many other members of the community to also follow the tour without creating a huge crowd.

Figure 35, A potential opportunity to share insights with a wider virtual audience?
[Source: “Place Making and the Politics of Planning” (Keesmaat 2013)]

Only the future will tell us if such public engagement and collaboration will work effectively; however, there is no doubt that it is precisely this kind of open opportunity that immersive VR has the potential to provide. Keeping in mind that we may still face some paradigm shifts, the next chapter explores what an immersive participatory action research (PAR) project might look like.

Chapter 8: A proposed participatory action research (PAR) project

The research methods outlined here were originally intended to be used for a participatory action research (PAR) project that would form the main body of this paper. However, in light of ongoing changes and recent developments in VR technology (such as Facebook's acquisition of Oculus and Sony's announcement of its own VR system) and a lack of co-researchers/participants, the research project was set aside in favour of a review of the literature and a survey of the state of VR applications in planning practice. Additionally, the decision to avoid focusing on any one product or VR solution acknowledges that this work might still be too close to the forefront of the current technological curve and that the technology may soon change and evolve, leaving any results to be only a quaint novelty.

Participatory action research (PAR)

In participatory action research (PAR), participants are co-researchers, involved throughout a research project from initial design to results and final analysis (W. F. Whyte 1991). Much as the highest levels of Arnstein's ladder of citizen participation, or the IAP2 spectrum of public participation, are about empowering the public, PAR places an emphasis on doing research with participants rather than on, or for, them. As the principles and goals of PAR justifiably idealize a long-term commitment to working with a community, some might question whether a PAR project is actually the best place to first study the potential of a new and unestablished approach to visualization. Of course, a reasonable counterpoint is that the actual context of a real community not only is the best place to evaluate real-world applications, but that it also offers an opportunity to help bridge the 'digital divide' – often a major concern with regards to research about technology and civic engagement (Norris 2001).

As previously discussed, an introduction to new technologies can help communities leapfrog over intermediate stages. While the wider public may not typically have experience with (or access to) immersive VR systems, even a brief introduction to such technologies can change the way participants think about their environment. There is, however, no doubt that PAR can add to the complexity of a research project and, despite PAR's considerable merits, it is impossible to really do PAR if a project can only be run for a limited amount of time. In the absence of long-term commitments which allow the research process to be cyclical, efforts to engage in PAR will probably fail.

Proof of concept: VR system used

Although no formal research was conducted, some informal proof of concept work was conducted on several fronts and it seemed valuable to document and explain the technical steps involved for future investigators who might want to undertake such a project over the next few years. Harnessing the advances made by Oculus, this work used an early pre-consumer development version of the Rift that was released in 2013; new versions of the Rift, however, are already much more advanced than the hardware used in this preliminary work. For ease of description, the proposed research methods revolve specifically around the use of the Oculus Rift as the principal product to be used in setting up an immersive VR system.

Note: Before Facebook bought Oculus, the wider technological community was ready to embrace the Rift as a prototype for a hardware standard. Choosing an appropriate immersive VR system for further research will depend heavily on the direction of Facebook's plans for the Oculus Rift and any alternative options that Sony or other competitors unveil.

Selecting a site/project and research question

The selection of a development site or project is a traditional planning exercise. However, beyond the standard parameters of an academic or municipal community consultation, a PAR pilot project really requires the interest of stakeholders who are already committed to maximizing public participation and a willingness to truly engage with all stakeholders in the community. Ideally, the research project would complement an existing initiative wherein the ensemble of all stakeholders would invite the participation of investigators to help explore the potential of VR visualization in the planning context.

As expected, the first step is formulating a research hypothesis. While a PAR project would mean agreeing on a research direction as a group, the basic research question would be to determine whether or not the use of a VR system works as an effective visualization tool for public participants. There would be room here to consider different kinds of VR systems and their corresponding strengths and weaknesses. Depending on the time and resources available to the project, the research might not only consider the effectiveness of visualization with regards to the planning process but also make use of HCI research to study participants' interactions with the VR systems. As addressed in the next chapter on directions for further research, there is a growing need for multidisciplinary research in these new technological arenas and it is extremely important to involve the public in considering how such research is undertaken.

Proof of concept: site selection

As a test and without any participants, I decided to start my process experiments with an environment that was familiar. My parents live in a suburban Montréal neighbourhood, typified by single-family detached homes in close proximity to 8- and 14-storey apartment and condo buildings, where large residential developments are sometimes proposed. There is a nearby narrow lot that is undeveloped and which is typical of an opportunity for infill.

Preparing to collect data for VR modeling

To prepare for modeling, interviews with the whole community (individual members, institutional actors, commercial actors, etc.) should gather information to use as the groundwork for a preliminary proposal. From here, a detailed action plan can be developed for how data will be collected involving the consent and participation of all stakeholders. Generally, data-collection will involve a mix of private and public data: cadastral plans, municipal GIS data, satellite or aerial images, community mapping, and possibly even historic family photos of a neighbourhood depending on what is needed or volunteered. Having collected the necessary data to capture as much of the appropriate content as possible which will give context to the environment, the next step is to model the test environment.

Environment modeling and data portability

To create a comprehensive virtual environment in any one software program is usually a prodigious effort in and of itself. Unfortunately, modeling tools which are best suited to a single-use context may have shortcomings that restrict data interoperability. Because it is usually necessary to work with multiple software programs over the course of a full project, bringing virtual environments to life can quickly become very difficult. Programs can have different implementations for handling either open or proprietary file formats and results may not always be as expected.

The ability to export and import digital assets between software programs while preserving as much information as possible is known as data portability. For ease of portability, it helps if one can minimize the number of programs and file formats involved in the overall process; this, however, means quickly locking down an established process based on fixed choices. This may appear to reduce your flexibility but you cannot afford to make changes to these decisions later on in the process. If a collaborator shares a model only to discover that it is in an incompatible format, that contribution will be wasted regardless of how effective or extensive it is.

Proof of concept: preparing a base map and basic environment

To prepare for the process of modeling, the first item I secured for my early tests was cadastral lot data. Using SketchUp's integration with Google Earth, aerial imagery for the neighborhood was also imported to serve as the base map for the construction of a quick and simple conceptual model. As proof of concept for a richer environment, lot lines were drawn according to the cadastral data in order to prepare the basic environment for a more detailed model.

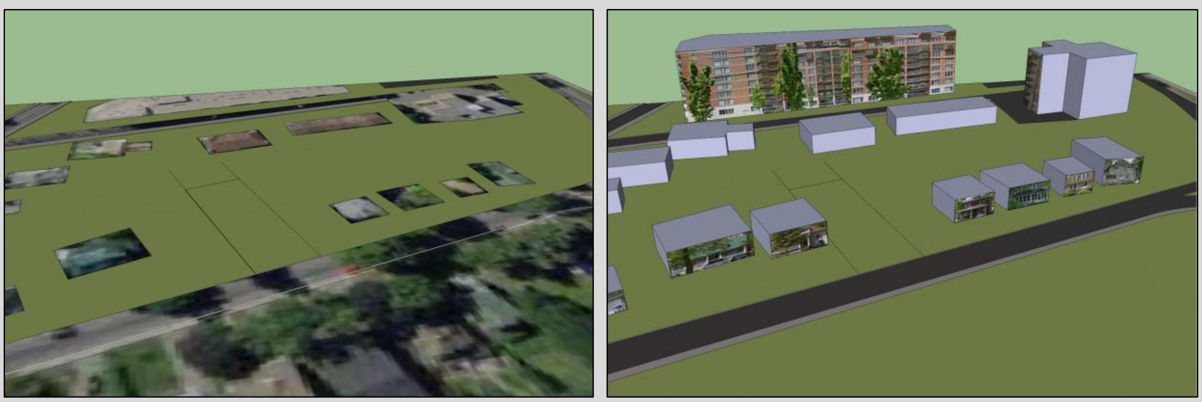

Figure 36, (a) Rough building footprints, and, (b) simple blocking and photo-textured building faces. [Source: original content, Google Earth and StreetView for photo-textures]

Modeling an extendable environment: considering future modifications

The choice of a modeling approach will ultimately be based on the VR system and the intended range of interaction in the final environment. The VR system will define the environment in terms of its role as the final content delivery platform (it has to be able to run whatever is modeled) whereas the intended range of interaction will usually define whether the research project is closed on delivery or remains open. In other words, can further changes be to the environment be made after the initial research goal is satisfied?

As previously explored, immersive VR is defined by being interactive in real-time; however, there is a wide variation between interaction that is limited to navigation in a static environment, interaction in a dynamic environment with fixed options (i.e. window frames can be blue, green, or red), and interaction in a dynamic environment with unlimited options (i.e. windows can turn into doors). While the last option may appear limitless in its freedoms, chaotic, or both, it is a real decision that faces the creators of all virtual environments or worlds. In the case of a PAR project, the question for participants is whether they want the created environment to answer the task of addressing challenges and opportunities in one particular context, or will its use be extended to all manner of proposals and applications, planning-related or otherwise?

In the case of the Oculus Rift, a PAR project could be custom built with the software libraries (defined implementations of behaviours) that Oculus provides but the easier approach for extendibility is to take advantage of the Rift's integration with Unity, a 3D engine that is widely used for game development but which is also used for simulation, visualization, and training. Of course, the trade-off with using Unity is that it is not cheap: Unity Pro has base license fees of $1500 per user (or $75/month), although those interested in 'serious' applications are advised to contact Unity for other licensing arrangements (Unity 2014). Unfortunately, it is still likely to be much more accessible as a solution for most researchers than programming a custom 3D graphics engine.

Obviously, the limitations of both approaches are representative of the difficulties involved in harnessing technological advances in a manner that is accessible to the wider public and which challenges the ideal of complete participation throughout the process. However, these barriers will not simply disappear if we choose to ignore technological offerings that are out of reach. Discussion of this decision should involve the whole community and, ideally, opportunities will arise for open and shared tools.

Capturing the existing environment

A process of preliminary environment modeling can streamline the task of turning basic 3D models from a standard format into more dynamic and malleable objects in the VR environment. The heart of environment modeling is, however, defined by a basic tension which must first be addressed. This tension usually appears when decisions are being made about the prioritization of photorealism and functional realism: acknowledging caveats about representation, the former aims for replication which is as accurate and exact as possible (as is typical of landmark modeling), while the latter prizes function over form to facilitate quick and easy mass replication (as seen in Esri CityEngine).

Ideally, the former could be done very easily with photogrammetry, but photogrammetry is even less established than immersive VR. Photogrammetry uses relative positioning and mathematics to estimate the best way to stitch together observed reference points (typically from photos) into 3D models. While photogrammetry holds incredible potential for capturing the existing environment, it has long been held back by limits in computer processing power and sensor technologies.

Photogrammetry has gained substantial ground as computers have grown more powerful and sensor technology advances have improved the resolution at which reference points are captured but important issues of scale remain. Applications like Autodesk's 123D Catch offer an easy path to replication and are acclaimed by many technological hobbyists and enthusiasts exploring 3D printing. However, while photogrammetry is theoretically just as applicable to buildings as it is to smaller objects, the increasing complexity of reference points at the street scale currently prevents it from being a feasible solution for most researchers.

Figure 37, A rough but relatively good photogrammetry model captured in Autodesk's 123D Catch. [Source: "An Old Building in Cork" (Otani 2012), License: CC BY-NC-SA 3.0]

Nevertheless, it is highly likely that intricate photogrammetry solutions are being developed behind closed doors. While Microsoft first acquired and showcased their Photosynth application in 2006, the real suspect is undoubtedly Google. With a wealth of geo-coordinated StreetView photos from their mapping vehicles (with higher-resolutions than are likely available publicly), Google has a clear advantage over most initiatives to build complete cityscapes. Photogrammetry, however, is not the only mapping technology at play in virtual city-building initiatives.

LiDAR (Light Detection And Ranging) actually uses a similar mapping approach; however, while being technically more coherent, it is likely to be outside the reach of most researchers. LiDAR systems use laser range-finding to scan millions of points into extensive datasets. Because LiDAR becomes more cost-effective than photogrammetry when working with huge datasets, LiDAR has typically supplanted or been blended with photogrammetry on larger projects. In 2012, there were reports that Nokia was using LiDAR to digitize city streets in an effort to rival Google (Kelion 2012); with Microsoft's recent acquisition of Nokia and its mapping services, it is very probable that these research initiatives are continuing (Microsoft 2013).

Figure 38, An example of LiDAR-captured point data in New York City.
[Source: "Nokia Maps digitises streets to battle Google's threat" (Kelion 2012)]

Another important consideration, but one which photogrammetry and LiDAR by themselves neglect, is that a building can be both a single object as well as the sum of its parts. In this regard, a focus on functional realism makes an important difference. As opposed to modeling an exactly replicated building which can only be manipulated as a whole, a functionally realistic model – built from component pieces in a similar manner to the real building it approximates – can be more easily altered and offers a greater opportunity for participants to suggest or consider alternative development choices in the planning process. However, in light of the new debate surrounding the practicality of 3D-printed houses, as showcased (with slightly different design focuses) in the Netherlands (Wainwright 2014) and China (Burgess 2014), it is likely that this issue of single-object versus composite-object will be revisited.

Proof of concept: photorealism and functional realism in modeling

After having modeled several types of housing stock (e.g. single-detached, row houses, mid-rise) in the neighborhood as simple photo-textured blocks, a slightly more functional model was produced.

Figure 39, Greater functional realism as seen in the open porch of an unfinished model.
[Source: original content, Google StreetView for photo-textures]

Of course, if resources allow, it is possible for a model to exist in both composite and component forms; any modern building whose construction followed an exact model (e.g. BIM) is a case in point. While we will not tackle the issue here, this also opens an important discussion about objectivity versus subjectivity in modeling. Depending on the scale of the environment being considered and whether or not the research focus encourages participants to delegate the modeling to others or undertake it themselves, modeling software choices vary: typical design and engineering options like AutoCAD or SketchUp can emphasize precision and scale, while software packages like 3ds Max or Blender are more organic, with a focus more akin to sculpting than drafting.

In the event of participatory modeling, participants who are ready to contribute their ideas communicated in model form will, in the absence of instruction or research funding, probably benefit most from modeling software that is relatively easy to use (e.g. SketchUp) and inexpensive or free (e.g. Blender). Again, while there is some standardization among common file-formats, it is extremely important that decisions about software compatibility vis–à–vis research goals be made very early on. Apprehensions about modeling ability may even be negligible in a research project emphasizing visualization with a degree of abstraction.

Comparable to the work of Denmark's Geodatastyrelsen (the Danish government's geodata agency) in recreating a quoted 1:1 ratio version of Denmark in the quasi low-resolution blocky sandbox world of the popular independent game, *Minecraft* (Farokhmanesh 2014), the level of detail necessary in modeling an environment for a participatory research project is entirely dependent on the goals that are chosen and may even be completely independent of the effectiveness of the visualization. For example, a certain degree of abstraction may initially encourage participants who are worried about messing up a photorealistic environment but may later hinder final decisions about smaller details or features. As such, all of these considerations are important to discuss with participants when modeling an existing environment.

Figure 40, Møns Klint: (a) scale model of Denmark in *Minecraft* above, and, (b) reality below.
[Sources: (a) "Danmarks frie geodata i en Minecraft-verden" (Kortforsyningen 2014), (b) "2008 09-07 09-08 Dänemark 319 Moens Klint" (Allie_Caulfield 2008), License: CC BY 2.0]

Transforming the environment from modeled to malleable

No matter the choice of modeling software, the need for standardization becomes evident when introducing the potential for participant interactivity to the modeled environment. In order to allow immersive real-time manipulation of the modeled environment by a group of participants according to predefined or open parameters, the virtual environment must be exported from modeling software and imported into either a licensed or custom graphics engine, including software libraries for both VR display and input from participants. While the goals of the PAR project will define the full range of interactions necessary, libraries for basic navigation will typically set the baseline for interactivity.

Just as Lego blocks can be used in traditional planning exercises to represent almost anything participants might imagine, immersive VR environments also free participants from the limits of existing realities. However, whereas physical Lego blocks may be quickly modified for almost any new purpose, direct and immediate manipulation of the VR environment by participants is not so straightforward. Those who wish to emphasize complete freedom of imagination will require unlimited foresight when it comes to potential model configurations, which is perhaps indicative of the fact that this is not the kind of visualization that immersive VR environments serve best.

Figure 41, Lego blocks used as a visualization tool in a population planning exercise. [Source: "Learning, again, why plans sometimes fail" (Newsom 2013)]

Proof of concept: transferring 3D models to a graphics engine

To begin the process, I exported the test environment from SketchUp as COLLADA (COLLAborative Design Activity), filename extension '.dae' – "an open standard digital asset schema for interactive 3D applications" (COLLADA 2007). Then, to address some minor aesthetic details I imported the file in Blender, made some texture changes, and exported the updated version in the proprietary FBX (Filmbox) file format, extension '.fbx' – another common format for digital content. Finally, I imported the FBX file into the free version of Unity available to private and small business creators.

Note: This is a simplified record of my approach; it is not appropriate for all projects. Porting models through multiple formats and software packages will have varied results and researchers/participants should experiment to determine what type of graphical production pipeline best suits their needs.

Instead, immersive VR is better used to flesh out proposed scenarios which draw on the ability to capture an additional sense of space, allowing participants to size up new ideas at a human-scale. Given that the aim of a PAR project would be to engender forms of public participation which empower participants or at the very least maximize their collaboration, there is a clear need for the modeling and scenario-running to be iterative. Changes in participants' experience of the scenarios being run will inform the modification of elements in the environment so that those elements can be directly altered and compared in revised scenarios.

Building on the proposed scenario in Chapter Seven where immersive VR could contribute to empathetic education in the context of accessibility planning, PAR's promotion of co-learning and shared knowledge would give participants the opportunity to integrate this collaborative learning into revised and remodeled scenarios that reinforce PAR's commitments to social equity and accessibility (McIntyre 2008). As the initial virtual environment is extended and multiple configurations are modeled for each scenario, participants will benefit from a rich body of urban features that can be easily altered on the fly. Furthermore, this ability to make real-time comparisons does not have to be limited to only the built environment but can also encompass the natural environment. Besides the ability for *in situ* sun and shadow studies, participants in floodplains could dynamically explore the effects of rising sea levels resulting from the melting of polar ice caps.

Proof of concept: participant manipulation of the natural environment

With the modeled environment imported into Unity, I re-adjusted textures, deleted the default camera, and added the Oculus Rift libraries for Oculus' camera (stereoscopic and linked to the Rift's head-tracking) and player-movement implementations. Next, I made a small change to the default lighting to give participants direct control of the sun's placement in the sky. While I did not position the sun to realistically reflect the actual orbit of the earth, this small adjustment demonstrates the potential for sun and shadow studies in immersive VR environments.

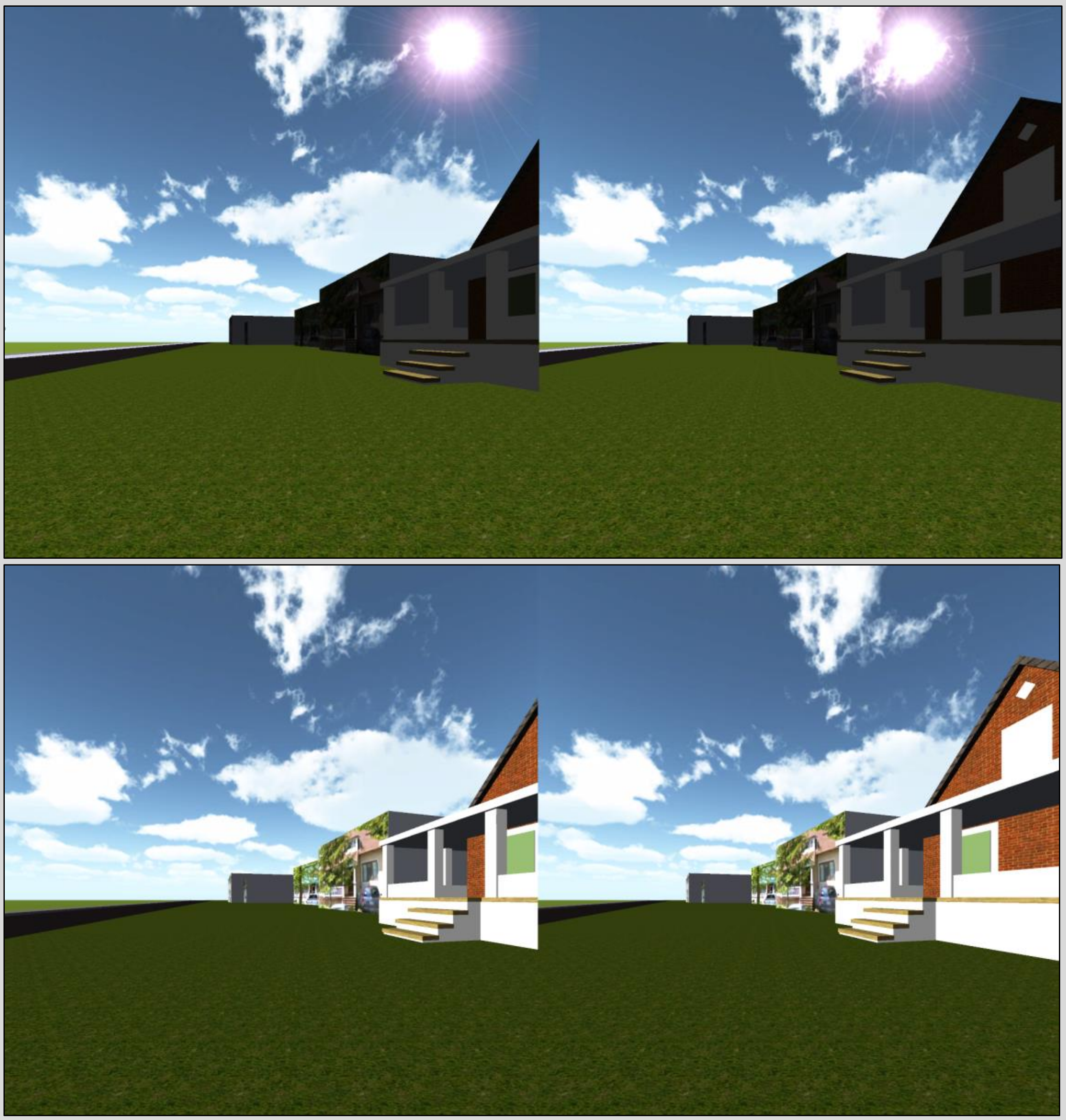

Figure 42, (a, b) Stereoscopic views of alternate lighting contexts with respect to the sun's position. [Source: original content, Google StreetView for photo-textures and Unity for skybox texture]

Proof of concept: participant manipulation of the built environment

Turning my attention to testing a simple method to scale models, I selected three basic Montréal buildings from among the models shared publicly in SketchUp's free 3D Warehouse. I set them up in SketchUp without any serious consideration for scale and then imported the whole environment into Unity as previously described. Finally, I wrote a short C++ function in Unity to rescale an object and included it in the project. While not very sophisticated, it was an easy and effective proof of concept.

Figure 43, Two shots of the same scene: (a) before, and, (b) after adjusting the duplex's height. [Source: original scene, Unity for skybox texture, models (left to right): "Box house duplex Montreal 01" (icimcp 2013), "Rue Notre-Dame ouest, Montréal, QC" (nicolas.dore 2007), and "Le Square Phillips Hôtel & Suites" (Potenza 2010)]

The pseudo code which follows outlines the method by which participants within the VR environment can change the height of a modeled building in real time with only a single key stroke.

```
include relevant libraries
public class {
   private function {
      initialize {
         identify target
      }
      update {
         get input {
            transform target scale
         }
      }
   }
}
```

In practice, a method to make a building appear or disappear at will, or to deform a model's mesh (the collection of vertices, edges, and faces which define a model's topology) is not vastly different: some projects may substitute alternate meshes, others may use predefined animations. Either way, even if the implementation of particular methods is not clear to all, the reasoning for the provision of these ranges of interactions should definitely be understood and supported by the participants.

Note: Again, this is only a record of my approach; there may be better approaches and other projects may have different requirements.

Potential physiological effects of immersive VR

Having briefly covered the process of modeling an existing environment and transforming it into an immersive VR environment, it is worth turning our attention to some of the specific details of immersive VR system use that can affect participants in an unexpected and/or unpleasant way. Wearing a fully immersive VR headset involves a completely novel stimulation of our senses and there are inevitable issues of physiology associated with the experience. While cases of physical discomfort are the exception rather than the rule, participants' experiences are uniquely tempered by their physical anatomy.

Given that immersive VR currently depends almost entirely on deceiving our vision through the use of stereoscopic displays (creating the illusion of depth and hence 3D), it should be no surprise that our eyes typically play the biggest part in determining whether or not the immersive VR experience is pleasant or unbearable. Because the stereoscopic approach shows a different image to each eye, the ideal configuration for participants is one in which the distance between the virtual cameras defining each image is exactly equal to the chief characteristic that defines our everyday experience of vision, our inter-pupillary distance (IPD). To better understand the impact that an inexact inter-camera distance (ICD) might have, imagine that your left eye continues to work normally but that your right eye now transmits visual information to your brain from the perspective of your right shoulder: in addition to rapidly developing a headache from the mismatched information in your brain, you would also be likely to injure yourself trying to walk down a flight of stairs.

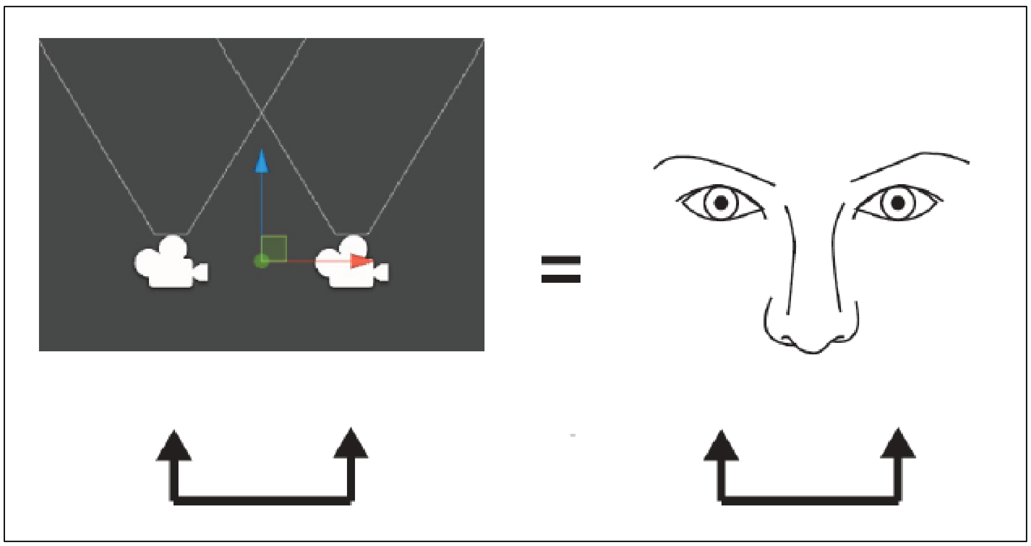

Figure 44, An image demonstrating how the ICD should equal the IPD.
[Source: *Oculus VR Best Practices Guide*, v.0.008 (Yao, et al. 2014)]

While the default ICD almost never exactly equals a participant's IPD and is not always easy to modify, for many participants there is no discomfort. Additionally, even though extended use with an unadjusted ICD can eventually make participants nauseous, the human brain is incredibly proficient at adapting to new stimuli. In short, repeated use can help the brain grow accustomed to extended periods of visual dissonance when wearing an unfigured headset but, ideally, extended use should only happen when time has first been set aside to correctly configure the ICD for a participant's IPD. Regardless, even those who experience zero discomfort should track their usage to minimize eye strain.

Understandably, some participants are never willing to give immersive VR a second chance if they experience any initial nausea. Furthermore, some participants experience continual feelings of nausea even with repeated use. In both cases, it is not always clear that an inexact ICD is at fault, and discomfort may be due to latency in graphics rendering or inner ear disorientation. Similar to spinning in a circle, if participants cannot keep track of a moving horizon and their balance feels offset, they are much more likely to feel ill.

Preparing a testing procedure and safety waiver

Despite friendly warnings concerning possible physiological issues, some people will be eager to experience immersive VR regardless of the discomfort their body may be trying to communicate. While it is important to tell participants that they should take a break at the first feeling of even the slightest discomfort, some individuals try to ride their way through any initial discomfort. This rarely, if ever, works. As such, it is very important to take the time to fully explain and describe potential physiological effects. Furthermore, the provision of a safety waiver will serve to highlight the fact that participants have been made aware of these issues and that they accept full responsibility for their own well-being. Ultimately, "better safe than sorry" is good guidance; some participants who may expect discomfort, will be delighted to discover they are unaffected.

Figure 45, VR demonstration station with safety warning in New South Wales, AU.
[Source: "Oculus Rift: Royal Adelaide Show 2013" (Shenn 2013), License: CC BY NC-ND 2.0]

Proof of concept: discomfort amongst a host of informal demonstrations

I have shared the first experience of immersive VR using the Oculus Rift with almost a hundred people, including acquaintances, friends, fellow students, school faculty, neighbours, extended family, family friends, and even relative strangers, to whom I have given informal demonstrations. Of course, what stands out among the number are the few cases in which people experienced enough discomfort to need to lie down for a while. Although such an admission might appear sufficient to discourage use (no matter how small a proportion of participants it represents), the reality is that these problems have been identified as priority targets for future improvement and the most recent hardware prototypes are said to be vastly improved in addressing these areas of discomfort.

Note: The transition of VR hardware prototypes into a release as consumer products will not happen without these challenges being addressed. By the time a major hardware company introduces a wide release of an immersive consumer-grade VR system, it will likely be possible to pursue in-depth immersive VR research without any significant fear of discomfort among research project participants.

PAR's advantage with regards to diverse demographics

Another benefit of PAR's emphasis on collaborative learning is that participants will be committed to sharing advice and techniques on how to use immersive VR. Furthermore, this shared learning will likely contribute to inter-generational interactions. As mentioned in Chapter Four, O'Coill and Doughty noted in 2004 that their use of a game development package as a participatory visualization tool highlighted increased involvement by children and those below thirty years of age (O'Coill and Doughty 2004).

In similar fashion, an increased adoption of immersive VR systems by younger participants would most likely be due to a familiarity with navigation in virtual worlds born from experiences with modern video and computer game technologies. However, given that early mainstream categorizations of immersive VR systems have almost exclusively designated these systems as entertainment devices, this reputation could be both a boon and/or a barrier depending on the research context: a strictly positive outlook would prize the opportunity to attract more youth, while a more cynical perspective might argue that older adults may refrain from sharing input and participating in the process. On the other hand, regardless of age, a significant proportion of people who are not typically active in public processes may find such approaches much more accessible than simply reading and comparing policy documents with printed visualizations.

Comparing and contrasting visualization tools

Ultimately, independent of other research questions, consideration must be given to evaluating whether or not immersive VR is more effective than other visualization tools, or if perhaps it serves a different function than more traditional tools. To answer this line of questioning, participants/co-researchers should compare and contrast how visualization communicates challenges and opportunities in their community, as modeled and/or presented in various forms such as:

1) printed images (e.g. composite scenes created in PhotoShop, or screen-captured 3D models)
2) presentation videos (e.g. site walkthroughs, or environmental fly-bys)
3) non-immersive VR (e.g. SketchUp, or interactive environments, on a normal display)
4) immersive VR, with or without augmented reality features (e.g. immersive interactive environments, experienced through headset displays or glasses)

With regard to comparing non-immersive VR and immersive VR systems, a fully-featured engine such as Unity can help to provide a control by using the exact same environment and digital assets, eliminating the potential for any differences that might arise while porting models from one software package to another. For example, the process for switching between an immersive and non-immersive VR system in Unity is as simple as swapping out the basic camera and controller libraries for a different implementation. As opposed to the time and effort which would have to be expended to reconcile all the features of independently created non-immersive and immersive environments, this approach is incredibly straightforward and does not compromise the overall integrity of the research design.

Iterative research: exploring results, sharing findings and trying new things

As has been mentioned, collaboration with the whole community is sought at every stage of a PAR project. Coming to the end of a project, is never really the end for PAR participants/co-researchers because they live and work in the very same environment that has been the subject of research. Given that participants/co-researchers both share in the experience of research and are directly affected by their own investigation, the results of PAR serve to inspire new questions: were any voices missing?

Was someone left out? How can the PAR process and/or the existing environment be further improved? How else can the community be strengthened?

With respect to evaluating the effectiveness of immersive VR as a visualization tool, PAR participants/co-researchers would also represent a wider public (communities in other neighbourhoods, cities, provinces, or even countries) in asking: can we continue to improve visual communication? How much does the storyteller's adage, "show; don't tell," apply to planning policy? How can communities do a better job of sharing tools and expertise to take advantage of new technologies like immersive VR? Any one of these questions by itself is valuable as a direction for further research but PAR also opens the door to real civic engagement because each participant/co-researcher is also personally invested: what will this look like in my community? Taking these important questions into consideration, the next chapter broaches the seemingly endless topic of directions for further research.

Chapter 9: Directions for further research

Moving beyond the immediate context of this paper, there are still many important questions and issues surrounding the integration of virtual reality and planning practice. Some of these topics are specific to planning but others are more general in scope. Besides discussions about the full potential for interactivity and the effects of stimulating additional senses, there are also questions about intellectual property, health and safety, public participation, and access to technology.

All of these topics deserve exploration and are relevant as directions for further research. Additionally, in order to prepare for a wider adoption of VR technology, planners must consider the effects of virtual reality beyond its use in planning practice. Heralding the rise of information and communication technology (ICT), arguments for the potential impact of telework on location theory have been made since the 1970s (Nilles 1976). In this regard alone, VR's qualities as an ICT raise serious questions which will affect wider planning policy decisions and that warrant careful investigation.

Before being able to properly discuss such issues, however, we must improve our ability to talk about VR in a meaningful manner. This paper represents an early step on that path but we are still far from having a basic common understanding of virtual reality. As such, a primary focus of future work should be concerned with improving descriptive language to explain different types of VR contexts.

Describing and classifying immersive environments

Though perhaps unknown to some readers, much has already been written about virtual environments and worlds. However, despite a diversity of research (which includes sociological studies into virtual weddings, funerals, and other rituals and rites) (Holtzman 1995, Heidbrink, Miczek and Radde-Antweiler 2011), the virtual environments that were studied have traditionally been experienced as non-immersive virtual reality. Due to previous hardware limitations, there has never been much opportunity or occasion to research immersive VR experiences in the same manner and at such a scale (e.g. social hierarchies, longitudinal patterns of use, etc.).

As work with immersive environments becomes more prevalent, it will be necessary to develop a better common vocabulary and terminology. While there is plenty to gain from building on non-immersive studies, a framework for categorizing interactivity in immersive environments as well as describing the range of senses which are engaged might be the most helpful contribution that could be made initially. As alluded to from the start, this paper has focused exclusively on visualization opportunities but there are even greater potential applications for VR that have yet to be realized in the stimulation of additional senses.

Scaling and layering VR: effect or affect, actors or audience?

The full experience of virtual reality in fiction has typically been envisioned as a multi-user exercise: the virtual environments of cyberspace full of avatars, operating in parallel to reality but with the opportunity for crossover agency (e.g. a virtual operator, or decker, opens or closes a door in the real world by means of a virtual switch). Elements of this conception have been seen in non-immersive VR systems but opportunities to experience large scale immersive environments with a similar potential for interaction have been rare. The limitations and rarity of cave automatic virtual environments (CAVE) notwithstanding, CAVEs have until now been the best option for those seeking a large immersive experience that can cater to more than one user. CAVEs, however, still cannot scale well for more than a handful of users.

Historically, the best example of early work on large immersive (though not interactive) environments is perhaps found in Disney's Circle-Vision 360° technology first developed in the 1950s and memorably experienced in a showing of *Canada 67* at the Telephone Pavilion during the 1967 World Expo in Montreal (Feldman, et al. 2011). With nine large curved screens creating a circular display that was about 7m (23 feet) in height and a little over 83m (273 feet) in circumference, the audience of hundreds was surrounded by an experience that placed them directly in a mediated environment (Brown 2014). Today, amusement parks have continued to produce large immersive multimedia attractions which are increasingly interactive, yet while the experiences engage a greater number of participants simultaneously than traditional CAVEs, the audiences are largely captive.

While we might be tempted to immediately categorize immersive environments by interactivity, it is important to consider that interactivity can vary based on modes of use. It is quite possible for an immersive system to provide an environment in which participants can switch between modes of interaction based on context. In response to such experiences of immersion, immersive VR systems would benefit from a UI (user interface) design which telegraphs meaningful participation and readily conveys whether the user is experiencing a subjective or objective mode.

Consider a user who interacts with a fully sensory experience, or perhaps only a soundscape: is she only able to witness an event, or can she influence it? Both modes have their place; a participant might first be asked to witness a conflict scenario in a planning context and then be asked to re-experience the scenario demonstrating how he would help mediate between opposing stakeholders. With such examples in mind, future researchers may want to define a spectrum of interactivity appropriate to context.

Ensuring accessible participation

Beyond the development of a common means for describing and classifying VR, further research should also evaluate how readily virtual reality technology is made available to the public in the planning process. While access to technology has already discussed at some length in this paper, the potential benefits of VR for public participation are meaningless without widespread opportunities for use. Although immersive VR is thankfully becoming more affordable, planners still have a responsibility to ensure that provisions are made to ensure that concerns about access are addressed in a manner which is socially equitable (e.g. providing free access through shared municipally-owned hardware in a library or community-centre context).

Additionally, a lack of technical knowledge should not be a limiting factor for participants. Efforts to educate and train citizens in the use of VR technology may seem daunting to planners who are fearful of taking on extraneous duties but this should not be seen as an individual burden. Instead this kind of context represents a great opportunity to partner with community groups who often already offer instructional classes on a variety of topics. Ultimately, further research will help determine the best course of action for municipalities and planners interested in undertaking educational projects.

Notes for PAR: building on public participation geographic information systems (PPGIS)

For those who are interested in pursuing further research on the use of virtual reality for public participation, it may be very helpful to review the existing body of work on PPGIS. In 2006, Renee Sieber published a PPGIS literature review and framework which covers many themes relevant to this discussion. These themes include: 1) a focus on *place and people* that is highly localized but with room for shared application, including a separation between stakeholders and the general public (a multi-dimensional conglomeration served by many different interfaces); 2) *technology and data* defined by extent, access, appropriateness, and representation; 3) *process* as constitutes systems of implementation, participation and communication, and decision-making; and 4) *outcomes and evaluation* which highlight explicit goals and measurement to avoid paying lip service to the ill-defined 'empowerment' of a generic branding of public participation (Sieber 2006).

Respecting legal issues and other concerns

Approaching user experience from a different angle, there is also considerable work to be done in establishing what kind of norms will govern VR use. What are the rights and responsibilities of participants with regards to their use of VR hardware? As touched on in Chapter Eight, there are currently issues of health and safety which we assume will be overcome; but further research may suggest otherwise. Will use be governed by age? What new forms of etiquette might be required for communicating through the medium of VR?

Some of these questions are closely tied to a desire to explore new horizons in understanding human-computer interaction (HCI) and/or challenging ontological quandaries, but others are hardly novel. For as long as developers have made promises about developments that were not yet built, legitimate questions concerning representation have existed; is what we see, what we get? It is not uncommon to hear stories of communities who feel that they were in some way deceived by appealing visuals that misrepresented the actual reality of development.

Another relatively mundane but potentially costly issue is the ever growing spectre of intellectual property (IP). In the longstanding debate about IP in the digital realm, some parties champion IP as a protector of innovation, while other see it as a traditional guard against the potentially disruptive nature of innovation. As will be seen in the next section, IP law has the potential to directly affect VR given that there may still be special legal considerations associated with 3D models which have not been widely considered.

Building ownership and related intellectual property (IP) concerns

With specific regard to the context of urban modeling, there may be unexpected legal ramifications surrounding the ownership of buildings. Consider this disclaimer associated with Sony's promotion of *inFAMOUS Second Son*, previously mentioned for its replication of Seattle's cityscape: "The Space Needle is a registered trademark of Space Needle LLC and is used under license" (Sony 2014). Whether or not the need for specific permission requirements would be waived in the case of model use by government actors, individual citizens and civil society actors must be careful.

If IP laws are used to control the use of virtual models based on the physical design and appearance of real buildings, the possibility of complex legal challenges cannot be ignored. In an interview with Chris Zimmerman, co-founder of Sucker Punch (the developer of *inFAMOUS Second Son*), Zimmerman discusses arrangements with the owners of the Space Needle that governed its use (IGN 2014). Even the use of landmark buildings that have predominantly been paid for with public funds (e.g. stadiums, hospitals, etc.) and which researchers might well assume fall within the public domain, may be stymied by management companies, the building's architects, or other private stakeholders.

Given that many of these potential issues and concerns are more evocative of barriers than opportunities, it is easy to suggest that they lack the appeal of other directions for future research. However, while researchers may be discouraged by the restrictions that might arise from such research, this work is of the utmost importance if VR technology is to see serious adoption. In a similar vein, telework is an example of a type of use which is likely to be surrounded by extensive legislation and policy decisions precisely because of the importance of the paradigm shifts it may instigate.

Recognizing a potential labour shift to telework

Those who are interested in the future of telepresence and teleoperation will no doubt recognize the magnitude of the potential impacts on telework, and hence planning practice, which the wider adoption of VR may produce. As the automobile rose to prominence, Kingsley Davis observed that workers would likely be willing to live at a great distance from their place of employment were the temporal costs of commuting reduced to the point that they were no longer significant (Davis 1955). By the 1970s, the idea of telework or telecommuting (terms attributed to Jack Nilles) had captured something of that observation (Nilles 1976).

Nilles' book, *The Telecommunications-Transportation Tradeoff: Options for Tomorrow*, was born from a 1973 case study report of the same name which examined how advances in information and communication technology (ICT) had paved the way for an insurance company to decentralize some of its work to the suburbs of Los Angeles by preserving operation linkages through its telecommunications network. Today, telework is quite common and many professionals in various industries work from their homes, or coffee shops, as if they were virtually in an office.

Studies reporting increased job satisfaction and productivity notwithstanding (Cisco Systems 2009), telework has sometimes been criticized for its lack of 'face to face' social interaction and, as a result, telework policies have at times been cut or reduced (Miller 2013, Hesseldahl 2013). If these explanations for reductions in telework are taken at face value, it is not difficult to see how future iterations of immersive VR could fully address those concerns. Furthermore, as explored in the scenario from Chapter Six involving the heritage planner in Hong Kong, immersive VR has the potential to render distance completely negligible.

While it is easy to envision the vast potential that this kind of telework can offer, it is left as an exercise for future researchers to theorize about the possible effects on the location of labour and the debates which are likely to follow with regards to tax law. Once again, it bears repeating that the consequences of the wider adoption of VR may be immense; if planners do not take the time to consider these items for research they will fail in their responsibilities to the public interest. The small selection of directions for future research which have been considered in this chapter represents only the tip of the iceberg.

However, despite such warnings, virtual reality is not to be feared. If we are overwhelmed by the complexity of the interconnected nature of the reality presented, it is only because we have never hereto had the opportunity to interact with these systems at such varying degrees of abstraction. Returning to visual metaphors, it is easier for us to discern now that realists such as Courbet who pursued objectivity in their art actually were no less abstractionists than Kandinsky or Pollock. As we too try to capture aspects of reality in future VR research, we will no doubt discover more and more of reality in the mirror we hold up. With such hopes in mind, the final chapter brings this paper to its conclusion.

Further thoughts on future design issues and obstacles

As Levy observes, virtual worlds which can be created very easily today would have been very difficult and time-consuming to build even only ten years ago (Levy 2014). There is no doubt that great opportunities exist to take advantage of advances in visualization technologies but it is important to consider what kind of design issues still exist. For example, a recent news article that reports on the untapped potential of immersive VR to help younger people engage with planning issues emphasizes giving voice to "a different group of people" rather than speculating on whether older groups would also feel more empowered with this new technology (Hack 2014). Levy makes the reasonable suggestion that some people may never become adjusted to VR (Levy 2014).

The experience of running proof of concept demonstrations certainly seems to suggest that some people adapt instantly, some can acclimatise through repeated use, and some experience discomfort for hours after just a short period of use. Of course, as has been mentioned, that work was done with the first widely available Oculus Rift prototype development kit. Since having been acquired by Facebook, the second version of the development kit has since shipped and reviews have generally been much more positive with regards to the type of hardware display lag that seems to be the root of most physical discomfort.

Again, navigation issues cannot be overlooked. Many younger users find that they can intuitively navigate while wearing a HMD without the need to look at any controllers in their hands. However, others have great difficulty when they cannot see their actual hands. While workarounds may be found, it is likely that frustrations will exist for some time for those who have tried to play normal computer and video games and have needed to continually look back and forth between the display and the controller in their hands.

Beyond physical interactions with VR systems, there are also questions about what level of detail is appropriate for different project scales. In the very simplistic environment created for this project, it did not take much detail for neighbours and friends to recognize the immediate environment of the street and its main intersection along the water. However, in approaching the slightly more detailed house, questions would begin about whether the stairs could be climbed and if it was possible to stand on the porch. Then, once these actions had been taken, the familiarity of the environment would begin to prompt users to ask more and more specific things until some limitation of the environment quickly appeared. It seems evident that the most appropriate use of immersive VR systems and environments will have to be guided on a case by case basis with regard to the scale at which planners are working.

Finally, despite the increasing availability of new VR technology, cost is likely to continue to be an issue. It is probable that each release of these products will introduce substantial improvements until the technology stabilizes. Early adopters will have to continually upgrade their systems or might regret their earlier purchases. Interestingly, Samsung's recent VR Gear announcement is directly tied to its line of Note 4 smartphones which serve as the display for their headset when not being removed from the system and simply used as phones. This cross-over with smartphones is likely to boost adoption but may also create divisions between phone manufacturers. Either way, planners will soon have to decide if it is worth waiting for a standardized platform or whether they should start early to learn more about the surrounding body of work which will only continue to grow.

Figure 46, A Samsung smartphone works as a removable display in Samsung's new VR headset. [Source: "How Samsung's VR headset convinced John Carmack to join Oculus VR" (Gilbert 2014)]

Chapter 10: Conclusion

Having reached the end, it is unlikely that any readers who are still unconvinced about the importance and relevance of VR to planning practice will find a justification that can sway them here. Nevertheless, the arguments for the use of virtual reality as a visualization tool for public participation in planning practice are simple and easy to reiterate. First and foremost, virtual reality is already here. The importance of visualization for civic engagement has already been widely established and, as planners, we already use non-immersive VR extensively for that purpose in planning practice. Our primary rationale in these cases is to make complex information accessible and to clearly communicate ideas which have no other appropriate representation in reality. Whether or not, planners are ready to adopt immersive VR, it is becoming increasingly rare to find a planner who has never used Google Earth or Street View, 3D modeling in sun or shadow studies, or 3D visualizations of any kind in GIS (topography, height-adjusted building footprints, etc.).

Having met the research objectives of this paper by presenting a review of the current state of research on VR in planning, explaining how we have arrived at this juncture, and demonstrating how VR's application as a visualization tool might be applied to common planning scenarios, the real argument that this paper delivers is that there are even greater potential benefits to virtual reality use in immersive VR systems and augmented reality (in whatever way one ultimately chooses to classify it) than have yet been realized. As reviewed, there is clear evidence that such systems are being used in novel and innovative ways in other industries and fields. Given that we do not have the same resources available to us (as opposed to medicine or manufacturing), those applications have until recently been largely out of planning's reach as a profession. While participatory planning work has been done with CAVEs and non-immersive VR (Hanzl 2007), as well as GIS (Sieber 2006, Voss, et al. 2004), extensive research on immersive VR in participatory planning has largely been prevented by the barriers of cost and limitations in VR technology itself. These barriers are now disappearing, and there is great opportunity for planners to study the full breadth and depth of what immersive VR can contribute in allowing citizens to envision changes in their existing environment *in situ*.

In conclusion, there is no doubt that the technology is still young and that we are still only on the cusp of further advances. However, in order to give serious consideration to the effects that these advances will have on planning practice, planners need to begin to understand the topics of discussion that are guaranteed to arise in the years to come. If we choose to ignore the medium, we will only be ostracizing our profession and neglecting our responsibility to the public interest. Virtual reality has incredible value as a visualization tool for public participation in planning practice as will be seen in years to come.

Bibliography

Adams, Douglas. *The Hitchhiker's Guide to the Galaxy.* London, UK: Pan Books Ltd., 1979.

Adams, Douglas, and Karey Kirkpatrick. *The Hitchhiker's Guide to the Galaxy.* Film. Directed by Garth Jennings. Produced by Touchstone Pictures; Spyglass Entertainment; Everyman Pictures; Hammer & Tongs. Performed by Martin Freeman, Mos Def and Sam Rockwell. Buena Vista Pictures, 2005.

Allie_Caulfield. "2008 09-07 09-08 Dänemark 319 Moens Klint." *Flickr.* September 8, 2008. https://www.flickr.com/photos/wm_archiv/2921100933 (accessed May 8, 2014).

APA. *Planning and Urban Design Standards.* Hoboken, NJ: Wiley, 2006.

—. "The Planners Guide to CommunityViz." *American Planning Association.* 2013. https://www.planning.org/plannerspress/authors/2011/communityviz.htm?print=true (accessed February 17, 2014).

—. "What Is Planning?" *American Planning Association.* 2013. https://www.planning.org/aboutplanning/whatisplanning.htm.

Appelbaum, Richard P. "The future is made, not predicted: Technocratic planners vs. public interests." *Society* 14, no. 4 (1977): 49-53.

Arnstein, Sherry R. "A Ladder of Citizen Participation." *Journal of the American Institute of Planners* 35, no. 4 (July 1969): 216-224.

Artaud, Antonin. "The Alchemical Theater." In *The Theater and its Double*, by Antonin Artaud, translated by Mary Caroline Richards, 48-52. New York, NY: Grove Press, 1958.

Beckman Institute. "Illinois Simulator Laboratory: CAVE." *University of Illinois at Urbana-Champaign.* February 2013. http://isl.beckman.illinois.edu/Labs/CAVE/CAVE.html (accessed April 4, 2014).

Beißwenger, Michael, Maria Ermakova, Alexander Geyken, Lothar Lemnitzer, and Angelika Storrer. "A TEI Schema for the Representation of Computer-mediated Communication." *TEI and Linguistics: Journal of the Text Encoding Initiative*, no. 3 (November 2012): 2-31.

Berners-Lee, Tim. "Foreward." In *VRML - Browsing and Building Cyberspace*, by Mark Pesce, xxi-xxii. Indianapolis, IN: New Riders, 1995.

Berrios, Olga. ""ushahidi en kenya"." *Flickr.* February 10, 2009. https://www.flickr.com/photos/ofernandezberrios/3269405041.

Black Desert Online. "Black Desert #CB2 Character Creation ." *YouTube.* April 6, 2014. https://www.youtube.com/watch?v=4TP4L1vHfpk (accessed September 1, 2014).

Blythe, Mark A., Andrew F. Monk, and Kevin Doughty. "Socially dependable design: The challenge of ageing populations for HCI." *Interacting with Computers* 17, no. 6 (December 2005): 672-689.

Brayj, Umberto. "Strollers, seniors, shopping carts & kids - but no curb ramps." *Flickr.* February 18, 2014. https://www.flickr.com/photos/ubrayj02/12621872755 (accessed April 29, 2014).

Brown, David. Personal communication. Montreal, QC, February 6, 2014.

Brown, David. "Special Issue: Computers and Planning, Editorial." Edited by David Brown. *Plan Canada* (Canadian Insitute of Planners / Institut canadien des urbanistes) 27, no. 4 (June 1987): 92-119.

Burgess, Matthew. "Are 3D printed houses practical? The experts weigh in." *Factor.* May 9, 2014. http://www.factor-tech.com/3d-printing/are-3d-printed-houses-practical-the-experts-weigh-in/ (accessed May 9, 2014).

Cairns, Paul, and Anna L. Cox. *Research Methods for Human-Computer Interaction.* Edited by Paul Cairns and Anna L. Cox. Cambridge, UK: Cambridge University Press, 2008.

Canada. "Canada's Action Plan on Open Government." *data.gc.ca.* August 1, 2013. http://data.gc.ca/eng/canadas-action-plan-open-government (accessed November 13, 2012).

Caro, Robert A. *The Power Broker: Robert Moses and the Fall of New York.* New York, NY: Knopf, 1974.

Carr, Austin. "Ford Taps Oculus Rift For Future Automobile Designs." *Fast Company.* January 6, 2014. http://www.fastcompany.com/3024328/innovation-agents/ford-taps-oculus-rift-for-future-automobile-designs (accessed January 20, 2014).

Center for Interactive Research on Sustainability. "Vizualisation Tools and Community Engagement." *University of British Columbia, Centre for Interactive Research on Sustainability (CIRS).* 2013. http://cirs.ubc.ca/research/research-area/visualization-tools-and-community-engagement (accessed December 2, 2013).

Chester. "Oculus Rift." *Flickr.* December 3, 2013. https://www.flickr.com/photos/chesterbr/11342555355.

Christakis, Dimitri A., Beth E. Ebel, Frederick P. Rivara, and Frederick J. Zimmerman. "Television, video, and computer game usage in children under 11 years of age." *The Journal of Pediatrics* 145 (November 2004): 652-656.

CIP. "Code of Professional Conduct." *Canadian Institute of Planners.* 2014. http://cip-icu.ca/web/la/en/pa/C59DDE35F1184B5E89385E53506C19F8/template.asp.

—. "What is Planning?" *Canadian Institute of Planners.* 2014. http://www.cip-icu.ca/web/la/en/pa/3FC2AFA9F72245C4B8D2E709990D58C3/template.asp.

Cirulis, Arnis, and Kristaps Brigis Brigmanis. "3D Outdoor Augmented Reality for Architecture and Urban Planning." *Procedia Computer Science.* Elsevier, 2013. 71-79.

Cisco Systems. "Cisco Study Finds Telecommuting Significantly Increases Employee Productivity, Work-Life Flexibility and Job Satisfaction." *Cisco Systems.* June 25, 2009. http://newsroom.cisco.com/dlls/2009/prod_062609.html (accessed December 11, 2013).

City of Edmonton. *City Policy (C551): Residential Infill Guidelines: A Manual of Planning and Design Guidelines for Residential Infill in Mature Neighbourhoods.* Edmonton, AB: City of Edmonton, 2009.

—. "fresh: Edmonton's Food and Urban Agriculture Strategy." *City of Edmonton.* October 2012. http://www.edmonton.ca/city_government/documents/FRESH_October_2012.pdf (accessed August 29, 2014).

City of Edmonton. *Municipal Development Plan - Bylaw 15100: The Way We Grow.* Edmonton, AB: City of Edmonton, 2010.

City of Mississauga. *Our Future Mississauga: Community Engagement and Directions Report.* Mississauga, ON: City of Mississauga, 2008.

City of Ottawa. "Encouraging and advancing public participation in Ottawa." *City of Ottawa.* September 8, 2003. http://ottawa.ca/calendar/ottawa/citycouncil/csedc/2003/10-07/ACS2003-CRS-SEC-0016englishFINAL.htm (accessed August 19, 2014).

—. "Encouraging and advancing public participation in Ottawa." *City of Ottawa.* October 22, 2003. http://app06.ottawa.ca/calendar/ottawa/citycouncil/occ/2003/10-22/csedc/ACS2003-CRS-SEC-0016.htm (accessed August 19, 2014).

—. "Public Engagement Guidelines and Toolkit." *Federation of Citizens' Associations of Ottawa-Carleton (FCA).* May 31, 2014. http://www.fca-fac.ca/Misc/engstrE.pdf (accessed August 26, 2014).

—. "Public Engagement Strategy." *City of Ottawa.* December 11, 2013. http://app05.ottawa.ca/sirepub/cache/2/fkzvilkridfd1a00sa3mqy03/973630829201410130016 9.PDF (accessed August 24, 2014).

City of Portland. *The Portland Plan.* Strategic roadmap, Portland, OR: City of Portland, 2012.

City of Toronto. "2010 Briefing Book." *City of Toronto.* February 11, 2011. http://www1.toronto.ca/city_of_toronto/city_managers_office/civic_engagement/council_briefings/files/pdf/briefing-book.pdf (accessed August 29, 2014).

COLLADA. "COLLADA." *COLLADA.* Jul 19, 2007. https://collada.org/mediawiki/index.php/COLLADA (accessed June 29, 2013).

CommunityViz. "Scenario 3D: Exploring a Scene ." *YouTube.* October 7, 2013. http://www.youtube.com/watch?v=FOxblOb0-zY (accessed January 27, 2014).

Couch, Justin. "An Introduction to VRML: The Basics." In *Late Night VRML 2.0 with Java*, by Bernie Roehl, Justin Couch, Cindy Reed-Ballreich, Tim Rohaly and Geoff Brown, 3-17. Emeryville, CA: Macmillan Computer Publishing, 1997.

CPI. "Citizens' Panel on Edmonton's Energy and Climate Challenges." *Centre for Public Involvement.* January 2013. https://d10k7k7mywg42z.cloudfront.net/assets/5162eca78ad7ca66810001eb/PRINT_ECP_EnergyClimateChange.pdf (accessed August 29, 2014).

—. "City-Wide Food and Urban Agriculture Strategy: Report on Citizen Panel Process & Recommendations." *Centre for Public Involvement.* July 26, 2012. https://d10k7k7mywg42z.cloudfront.net/assets/509af364dabe9d6d3b004a74/Citizen_Panel_Final_Report_September_2012.pdf (accessed August 29, 2014).

—. "What We Do." *Centre for Public Involvement.* 2014. http://www.centreforpublicinvolvement.com/ (accessed August 29, 2014).

Cudanin, Alden. "Granville and Georgia - 1955/2010." *Flickr.* January 7, 2011. https://www.flickr.com/photos/49576548@N05/5333215127.

Daily Camera. "@Last gets 'Googled'." March 15, 2006. http://it.tmcnet.com/news/2006/03/15/1460736.htm (accessed November 24, 2013).

dailylifeofmojo. "Woohoo! Free GPS nav from Google." *Flickr.* November 23, 2009. https://www.flickr.com/photos/24652987@N02/4128596089.

Dassault Systèmes. "3DVIA Virtools." *Dassault Systèmes.* May 22, 2013. http://www.3ds.com/products-services/3dvia/3dvia-virtools/ (accessed August 5, 2014).

Dassault Systèmes; Harvard University; Museum of Fine Arts (MFA) Boston. *Explore: a new dimension for archaeological research.* October 29, 2013. http://giza3d.3ds.com/index.html#explore (accessed November 24, 2013).

Davis, Kingsley. "The Origins and Growth of Urbanization in the World." *American Journal of Sociology* 60, no. 5 (March 1955): 429-437.

de Tocqueville, Alexis. *De la démocratie en Amérique.* 15th. Vol. 1. Paris: Imprimerie et Fonderie de Fain, 1835.

Dean, Jodi, Jon W. Anderson, and Geert Lovink, . *Reformatting Politics: Information Technology and Global Civil Society.* New York, NY: Routledge, 2013.

Digital Media Net. "@Last Software Announces SketchUp's Sectioning Tool." August 21, 2002. http://cad.digitalmedianet.com/articles/viewarticle.jsp?id=12339 (accessed November 25, 2013).

Donley, Matt. "History of Sketchup." *masterSketchup.com.* October 17, 2011. http://www.mastersketchup.com/history-of-sketchup/ (accessed November 24, 2013).

Données ouvertes Montréal. "ZoneCone.ca." *ZoneCone.ca.* 2014. http://zonecone.ca (accessed September 5, 2014).

Downes, Larry. "What Oculus's $2 billion payday teaches us about innovation." *The Washington Post.* March 26, 2014. http://www.washingtonpost.com/blogs/innovations/wp/2014/03/26/what-oculuss-2-billion-payday-teaches-us-about-innovation/ (accessed April 6, 2014).

Doyle, Simon, Martin Dodge, and Andy Smith. "The Potential of Web-based Mapping and Virtual Reality Technologies for Modeling Urban Environments." *Computers, Environment and Urban Systems* 22, no. 2 (March 1998): 137-155.

Edwards, Brent. "GIS Technology and the City of Laval." *Guest presentation for Planning Methods course lecture.* Montréal, QC, April 3, 2012.

Eifffage. "Visit Marseille in 2030." *Eifffage.* 2014. http://www.eiffage-phosphore.com/visit-marseille-2030 (accessed April 20, 2014).

Esri. *About Esri: History Up Close.* n.d. http://www.esri.com/about-esri/history/history-more (accessed January 24, 2013).

—. "Esri Acquires 3D Software Company Procedural." *Esri.* July 11, 2011. http://www.esri.com/news/releases/11-3qtr/esri-acquires-3d-software-company-procedural.html (accessed December 17, 2013).

—. "Marseille Urban Planning Project." *Esri.* 2014. http://www.esri.com/software/cityengine/industries/marseille (accessed April 13, 2014).

Failes, Ian. "Man of Steel vfx milestones." *fxguide.* June 24, 2013. http://www.fxguide.com/featured/man-of-steel-vfx-milestones/ (accessed September 5, 2014).

Farokhmanesh, Megan. "The entire country of Denmark has been recreated in Minecraft." *Polygon.* April 24, 2014. http://www.polygon.com/2014/4/24/5650592/the-entire-country-of-denmark-has-been-recreated-in-minecraft (accessed April 24, 2014).

FCA. "Citizen engagement." *Federation of Citizens' Associations of Ottawa-Carleton (FCA).* June 13, 2014. http://www.fca-fac.ca/Misc/engage.html (accessed August 24, 2014).

Feldman, Seth, et al. "Film at Expo 67: Canada 67." *Expo 67: Expanded Cinema.* 2011. http://www.yorku.ca/filmexpo/film.html#canada67 (accessed March 23, 2014).

Feshbach, Norma Deitch, and Seymour Feshbach. "Empathy and Education." In *The Social Neuroscience of Empathy*, edited by Jean Decety and William Ickes, 85-98. Boston, MA: Massachusetts Institute of Technology (MIT) Press, 2009.

Francia, Armi De, Kathleen Day, Daniel Schwirtz, and Keharn Yawnghwe. *La Faubourg Gouin.* Planning studio development proposal, School of Urban Planning, McGill University, Montreal: Faubourg Gouin team, 2012.

Galloway, Thomas D., and Riad G. Mahayni. "Planning Theory in Retrospect: The Process of Paradigm Change." *Journal of the American Institute of Planners* 43, no. 1 (1977): 62-71.

Gardiner, P. D., and J. M. Ritchie. "Project planning in a virtual world: information management metamorphosis or technology going too far?" *International Journal of Information Management* 19, no. 6 (1999): 485-494.

Gibson, William. "Fragments of a Hologram Rose." In *Burning Chrome*, 47. New York, NY: Arbor House, 1986.

Gilbert, Ben. "How Samsung's VR headset convinced John Carmack to join Oculus VR." *Engadget.* September 5, 2014. http://www.engadget.com/2014/09/04/samsung-gear-vr-john-carmack/ (accessed September 6, 2014).

Gladwell, Malcolm. "Creation Myth." *The New Yorker.* May 16, 2011. http://www.newyorker.com/reporting/2011/05/16/110516fa_fact_gladwell?currentPage=all (accessed March 24, 2014).

Goodman, Joy, and Stephen Brewster. "HCI and the Older Population." Edited by Joy Goodman and Stephen Brewster. *People and Computers XVIII - Design for Life: Proceedings of HCI 2004.* Leeds, UK: Springer, 2005.

Google. "71 E Upper Wacker Dr, Chicago, IL 60601, USA - approximate address." *Google Maps.* n.d. https://maps.google.com/maps?ll=41.887407,-87.625902&spn=0.008083,0.013078&t=h&z=17&layer=c&cbll=41.887152,-87.626309&panoid=opN0ottSGGaqd0n2O4vB_Q&cbp=12,311.75,,0,-1.52 (accessed April 28, 2014).

Hack, Christopher. "Try this 3D rollercoaster for the Oculus Rift headset. Could it help plan cities?" *The Guardian.* September 1, 2014. http://www.theguardian.com/cities/2014/sep/01/3d-rollercoaster-oculus-rift-city-planning (accessed September 5, 2014).

Hanzl, Malgorzata. "Information technology as a tool for public participation in urban planning: a review of experiments and potentials." *Design Studies* 28, no. 3 (2007): 289e307.

Hayek, Ulrike Wissen. "Which is the appropriate 3D visualization type for participatory landscape planning workshops? A portfolio of their effectiveness." *Environment and Planning B: Planning and Design 2011, volume 38, pages 921 ^ 939* 38, no. 5 (January 2011): 921-939.

Heidbrink, Simone, Nadja Miczek, and Kerstin Radde-Antweiler. "Contested Rituals in Virtual Worlds." In *Ritual, Media, and Conflict*, edited by Ronald L. Grimes, Ute Husken, Udo Simon and Eric Venbrux, 165-187. Oxford, UK: Oxford University Press, 2011.

Hesseldahl, Arik. "Yahoo Redux: HP Says “All Hands on Deck” Needed, Requiring Most Employees to Work at the Office (Memo)." *AllThingsD.* October 8, 2013. http://allthingsd.com/20131008/yahoo-redux-hp-says-all-hands-on-deck-needed-requiring-most-employees-to-work-at-the-office-memo/ (accessed December 10, 2013).

Hoffman, Hunter G., David R. Patterson, Eric Seibel, Maryam Soltani, Laura Jewett-Leahy, and Sam R. Sharar. "Virtual Reality Pain Control During Burn Wound Debridement in the Hydrotank." *The Clinical Journal of Pain* 24, no. 4 (May 2008): 299-304.

Holtzman, Steven R. *Digital Mantras: The Languages of Abstract and Virtual Worlds.* Boston, MA: MIT Press, 1995.

IAP2. "IAP2 Spectrum of Public Participation." *The International Association for Public Participation (IAP2).* 2007. http://www.iap2.org/associations/4748/files/IAP2%20Spectrum_vertical.pdf (accessed May 2013).

IBI Group. "What We Do - Planning - Public Outreach." *IBI Group.* 2014. http://www.ibigroup.com/what-we-do/planning/public-outreach/ (accessed March 30, 2014).

IBM. "IBM and City of Portland Collaborate to Build a Smarter City." *IBM.* August 9, 2011. http://www-03.ibm.com/press/us/en/pressrelease/35206.wss (accessed November 17, 2013).

icimcp. "Box house duplex Montreal 01." *SketchUp 3D Warehouse.* June 6, 2013. https://3dwarehouse.sketchup.com/model.html?id=f86249e4d59f775ccca68fa13c76228b (accessed August 27, 2013).

IGN. "Infamous: Second Son - Your Questions Answered - The Podcast Beyond Interview." *YouTube.* March 11, 2014. https://www.youtube.com/watch?v=3Ci3rUxWkBs (accessed May 20, 2014).

Jacobs, Jane. *The Death and Life of Great American Cities.* New York, NY: Random House, 1961.

Jervis, Peter. "Ontario SLAPP Schtick: Bill 83 is an abomination." *Financial Post.* April 10, 2014. http://business.financialpost.com/2014/04/10/ontario-slapp-schtick-bill-83-is-an-abomination/ (accessed August 19, 2014).

Kaliski, John. "Democracy Takes Command: New Community Planning and the Challenge to Urban Design." In *Urban Design*, edited by Alex Kreiger and William S. Saunders, 237-252. Minneapolois: University of Minnesota Press, 2009.

Keesmaat, Jennifer. "Place Making and the Politics of Planning." *slideshare.* City-Region Studies Centre, University of Alberta. January 22, 2013. http://www.slideshare.net/CityRegionStudies/place-making-and-the-politics-of-planning-jennifer-keesmaat (accessed February 24, 2013).

Kelion, Leo. "Nokia Maps digitises streets to battle Google's threat." *BBC News.* December 5, 2012. http://www.bbc.com/news/technology-20497719 (accessed April 29, 2014).

Kortforsyningen. "Danmarks frie geodata i en Minecraft-verden ." *YouTube.* April 24, 2014. http://www.youtube.com/watch?v=6rMebJWiNUQ (accessed April 24, 2014).

Kwartler, Michael, and Robert N. Bernard. "CommunityViz: An Integrated Planning Support System." In *Planning Support Systems: Integrating Geographic Information Systems, Models, and Visualization Tools*, edited by Richard E Klosterman and Richard K. Brail, 285-308. Redlands, CA: ESRI Press, 2001.

Ladd, Brian. *The Ghosts of Berlin: Confronting German History in the Urban Landscape.* Chicago, IL: University of Chicago Press, 1997.

—. *Urban planning and civic order in Germany, 1860-1914.* Boston, MA: Harvard University Press, 1990.

Lee, Nicole. "NASA's JPL maneuvers a robot arm with Oculus Rift and Kinect 2, points to more immersive space missions." *engadget.* December 23, 2013. http://www.engadget.com/2013/12/23/nasa-jpl-control-robotic-arm-kinect-2/ (accessed January 15, 2014).

Levy, Richard M. Personal communication., July 30, 2014.

Levy, Richard M. "Visualization of urban alternatives." *Environment and Planning B: Planning and Design* 22, no. 3 (1995): 343-358.

Lima, En-Mi, Tsuyoshi Honjo, and Kiyoshi Umekia. "The validity of VRML images as a stimulus for landscape assement." *Landscape and Urban Planning* 77, no. 1-2 (June 2006): 80–93.

Lockheed Martin. "On the Virtual Frontier: The Infantry Immersion Trainer." *Lockheed Martin.* September 2012. http://www.lockheedmartin.com/us/100years/stories/iit.html (accessed August 6, 2014).

Lynch, Kevin. *The Image of the City.* Cambridge, MA: MIT Press, 1960.

Macworld. "IDG's Macworld Announces Best of Show Awards." *Macworld.* July 18, 2002. http://www.macworld.com/article/1001503/18bestofshow.html (accessed November 24, 2013).

Männikkö-Barbutiu, Sirkku. "Networking for Accessibility: Elderly People and New Technology." Edited by Klaus Miesenberger, Joachim Klaus and Wolfgang Zagler. *Computers Helping People with Special Needs: 8th International Conference, ICCHP 2002 Linz, Austria, July 15–20, 2002 Proceedings.* Linz, Austria: Springer, 2002. 628-634.

Max3dmoon. "Drones regulations." *ReRoll.* February 8, 2014. http://forums.rerollgame.com/discussion/128/drones-regulations (accessed April 21, 2014).

McCracken, Kevin, and David R. Phillips. "International Demographic Transitions." In *Ageing and Place*, edited by Gavin J. Andrews and David R. Phillips, 36. New York, NY: Routledge, 2005.

McGraw-Hill Construction. *2009 SmartMarket Report: The Business Value of BIM.* McGraw-Hill Construction, 2009.

McIntyre, Alice. *Participatory Action Research.* Thousand Oaks, CA: Sage Publications, 2008.

Microsoft. "Microsoft to acquire Nokia's devices & services business, license Nokia's patents and mapping services." *Microsoft: News Center.* September 3, 2013. http://www.microsoft.com/en-us/news/press/2013/sep13/09-02announcementpr.aspx (accessed April 29, 2014).

Miller, Claire Cain. "Yahoo Issues a Statement on Work-at-Home Ban." *New York Times.* February 26, 2013. http://bits.blogs.nytimes.com/2013/02/26/yahoo-issues-a-statement-on-work-at-home-ban/?_r=0 (accessed December 10, 2013).

Minsky, Marvin. "Telepresence." *Omni Magazine*, June 1980: 45-51.

Moon, M. Jae. "The Evolution of E-Government among Municipalities: Rhetoric or Reality?" *Public Administration Review* 62, no. 4 (July/August 2002): 424–433.

Morgan, Russell E. "Technology Greets the Age Wave." *The Gerontologist* 45, no. 5 (2005): 704-710.

Mosca, Marco. "Watch Dogs, le très gros budget d'Ubisoft." *Challenges.* June 18, 2013. http://gamers.blogs.challenges.fr/archive/2013/06/18/watch-dogs-le-tres-gros-budget-d-ubisoft.html (accessed April 25, 2014).

Muller, Henk, Cliff Randell, and Chris Djiallis. "Personal position measurement using dead reckoning." *Proceedings of the Seventh IEEE International Symposium on Wearable Computers (ISWC'03).* 2003. 17-00.

Mundigo, Axel I., and Dora P. Crouch. "The City Planning Ordinances of the Laws of the Indies Revisited. Part I: Their Philosophy." *The Town Planning Review* (Liverpool University Press) 48, no. 3 (July 1977): 247-268.

Museum of London. "Streetmuseum." *Museum of London.* October 16, 2013. http://www.museumoflondon.org.uk/Resources/app/you-are-here-app/home.html.

Myers, Brad A. "A brief history of human-computer interaction technology." *Interactions* (Association for Computing Machinery) 5, no. 2 (March/April 1998): 44-54.

NASA. "Human Interaces Group: Future Robotic Interfaces." *National Aeronautics and Space Administration, Jet Propulsion Laboratory.* December 2013. http://www.hi.jpl.nasa.gov/projects/#future-robotic-interfaces (accessed January 15, 2014).

—. "NASA Robot Arm Control with Kinect." *YouTube.* December 23, 2013. http://www.youtube.com/watch?v=pqNC72fgetc (accessed January 15, 2014).

Newsom, Mary. "Learning, again, why plans sometimes fail." *Plan Charlotte.* June 14, 2013. http://plancharlotte.org/story/charlotte-connect-regional-sustainability-uli-realitycheck (accessed April 13, 2014).

nicolas.dore. "Rue Notre-Dame ouest, Montréal, QC." *SketchUp 3D Warehouse.* February 22, 2007. https://3dwarehouse.sketchup.com/model.html?id=91334c49de693f48bf78ff333f7ee0b (accessed August 27, 2013).

Nilles, Jack M. *Telecommunications-Transportation Tradeoff: Options for Tomorrow.* New York, NY: John Wiley & Sons, 1976.

Norris, Pippa. *Digital Divide: Civic Engagement, Information Poverty, and the Internet Worldwide.* Cambridge, UK: Cambridge University Press, 2001.

Northrop Grumman. "VIPE Holodeck." *YouTube.* December 5, 2013. https://www.youtube.com/watch?v=T7ro7RoGjes (accessed August 5, 2014).

O'Brien, Mary Grantham, and Richard M. Levy. "Exploration through Virtual Reality: Encounters with the Target Culture." *Canadian Modern Language Review/ La Revue canadienne des langues vivantes* (University of Toronto Press) 64, no. 4 (June 2008): 663-691.

O'Coill, Carl, and Mark Doughty. "Computer game technology as a tool for participatory design." *eCAADe2004: Architecture in the Network Society.* Copenhagen, Denmark, 2004.

OCPM. "2013 Annual Report." *Office de consultation publique de Montréal.* May 1, 2014. http://ocpm.qc.ca/sites/ocpm.qc.ca/files/pdf/references/documentsanglais/rapport-annuel-2013-eng.pdf (accessed August 28, 2014).

—. "Ma Ville, Ma Voix: 10 years of public consultations with Montrealers." *Office de consultation publique de Montréal.* November 2012. http://ocpm.qc.ca/sites/ocpm.qc.ca/files/OCPM_brochure10ans_EN.pdf (accessed August 26, 2014).

OMBI. "2012, Partnering for Service Excellence: Performance Measurement Report." *City of Toronto.* September 12, 2013. http://www.ombi.ca/wp-content/uploads/2012-Performance-Report-without-HR.pdf (accessed August 18, 2014).

—. "About." *Ontario Municipal CAO's Benchmarking Initiative (OMBI).* August 2014. http://www.ombi.ca/about/ (accessed August 16, 2014).

Ontario. "Bill 83, Protection of Public Participation Act, 2014." *Legislative Assembly of Ontario.* April 16, 2014. http://www.ontla.on.ca/web/bills/bills_detail.do?locale=en&BillID=2810 (accessed August 21, 2014).

Open Knowledge Foundation. "Open Knowledge Foundation." *Open Data – An Introduction.* n.d. http://okfn.org/opendata/.

Otani, Kazu. "An Old Building in Cork ." *Autodesk 123D.* July 16, 2012. http://www.123dapp.com/obj-Catch/An-Old-Building-in-Cork/748252 (accessed November 25, 2013).

Parish, Yoav I. H., and Pascal Müller. "Procedural modeling of cities." Edited by Lynn Pocock. *SIGGRAPH '01: proceedings of the 28th international conference on Computer graphics and interactive techniques, Los Angeles, CA, USA, August 12-17, 2001.* New York, NY: Association for Computing Machinery, 2001. 301-308.

Pelletier, Vincent. "2008 Quebec City QC Annual Meeting: Strategic Lawsuits Against Public Participation (SLAPPs) Report 2008." *Uniform Law Conference of Canada.* August 2008. http://www.ulcc.ca/en/2008-quebec-city-qc/235-civil-section-documents/448-strategic-lawsuits-against-public-participation-slapps-report-2008 (accessed August 19, 2014).

Pesce, Mark. *VRML - Browsing and Building Cyberspace.* Indianapolis, IN: New Riders, 1995.

Pixyul. "Partners." *ReRoll.* 2014. http://rerollgame.com/about/partners/ (accessed April 21, 2014).

Poplin, Alenka. "Playful public participation in urban planning: A case study for online serious games." *Computers, Environment and Urban Systems* 36, no. 3 (May 2012): 195–206.

Potenza, Luke. "Le Square Phillips Hôtel & Suites." *SketchUp 3D Warehouse.* June 18, 2010. https://3dwarehouse.sketchup.com/model.html?id=2c2f0ec3ffbcd84afac6099f3d4830fe (accessed August 27, 2013).

Québec. "Charter of Human Rights and Freedoms." *Publications Québec.* Edited by Éditeur officiel du Québec. August 1, 2014. http://www2.publicationsduquebec.gouv.qc.ca/dynamicSearch/telecharge.php?type=2&file=/C_12/C12_A.html (accessed August 20, 2014).

Ranasinghe, Nimesha, Adrian Cheok, Ryohei Nakatsu, and Ellen Yi-Luen Do. "Simulating the sensation of taste for immersive experiences." *Proceedings of the 2013 ACM international workshop on immersive media experiences.* Barcelona, Spain : Association for Computing Machinery, 2013. 29-34 .

ReROLL Community. "ReROLL Brick1 Announcement." *YouTube.* March 14, 2014. http://www.youtube.com/watch?v=gGkjm6jD7wU (accessed April 21, 2014).

Rizzo, Albert “Skip”. "Virtual reality and disability: emergence and challenge." *Disability and Rehabilitation* 24, no. 11-12 (2002): 567-569.

Rizzo, Albert “Skip”, et al. "Virtual Reality Applications to Address the Wounds of War." *Psychiatric Annals* 43, no. 3 (March 2013): 123-138.

rockman zx. "Watch Dogs Media Coverage." *NeoGAF.* April 21, 2014. http://neogaf.com/forum/showpost.php?p=108934587&postcount=130 (accessed April 28, 2014).

Rockwell, Norman. *early study for Freedom of Speech.*

Salter, Chris. *Entangled: Technology and the Transformation of Performance.* Boston, MA: MIT Press, 2010.

Sanyal, Bishwapriya. "Hybrid Planning Cultures: the Search for the Global Cultural Commons." In *Comparative Planning Cultures*, edited by Bishwapriya Sanyal, 3-28. New York, NY: Routledge, 2005.

Schön, Donald A. *The Reflective Practioner: How Professionals Think In Action.* New York, NY: Basic Books, 1983.

Seters, Paul van. "Approaching Global Civil Society." In *Critucal Mass: The Emergence of Global Civil Society*, edited by James W. St.G. Walker and Andrew S. Thompson, 25-39. Waterloo, ON: Wilfrid Laurier University Press, 2008.

Shenn, Jay. "Oculus Rift: Royal Adelaide Show 2013." *Flickr.* September 8, 2013. https://www.flickr.com/photos/44841911@N07/9932717093/.

Sheppard, Stephen R. J. "Guidance for crystal ball gazers: developing a code of ethics for landscape visualization." *Landscape and Urban Planning* 54, no. 1 (May 2001): 183-199.

—. *Landscape portrayals: their use, accuracy, and validity in simulating proposed landscape change.* Berkeley, CA: University of California, Berkeley, 1982.

Sheppard, Stephen R. J. "The ethics of Google Earth: Crossing thresholds from spatial data to landscape visualisation." *Journal of Environmental Management* 90, no. 6 (May 2009): 2102–2117.

—. *Visual Stimulation: A user's Guide for Architects, Engineers, and Planners.* New York, NY: Van Nostrand Reinhold, 1989.

Sheridan, Thomas B. "Musings on telepresence and virtual presence." *Presence* 1, no. 1 (1992): 120-126.

Sieber, Renee. "Public Participation Geographic Information Systems: A Literature Review and Framework." *Annals of the Association of American Geographers* 96, no. 3 (2006): 491-507.

Sony. "inFAMOUS Second Son™." *Playstation.* 2014. http://us.playstation.com/ps4/games/infamous-second-son-ps4.html (accessed May 21, 2014).

SpaceX. "The Future of Design." *YouTube.* September 15, 2013. http://www.youtube.com/watch?v=xNqs_S-zEBY (accessed September 17, 2013).

Stellingwerff, Marnix Constantijn. *virtual context.* Delft, NL: Delft University Press, 2005.

Steuer, Jonathan. "Defining Virtual Reality: Dimensions Determining Telepresence." *Journal of Communication* 42, no. 4 (December 1992): 73–93.

Stone, Michael. "Angel Flights." *UCLA Magazine.* October 1, 2011. http://magazine.ucla.edu/depts/quicktakes/angel-flights/ (accessed April 25, 2014).

Stone, Robert. "Serious games: virtual reality's second coming?" *Virtual Reality* 13, no. 1 (March 2009): 1-2.

Stoudt, Charlotte. "How the L.A. Noire makers re-created the city of 1947." *Los Angeles Times.* April 24, 2011. http://articles.latimes.com/2011/apr/24/entertainment/la-ca-noir-city-20110424 (accessed April 25, 2014).

Tach, Dave. "ReRoll story trailer shows off a geographically accurate in-game Montreal." *Polygon.* March 27, 2014. http://www.polygon.com/2014/3/27/5552986/reroll-trailer-video-montreal (accessed April 7, 2014).

Talbot, Thomas B., Kenji Sagae, Bruce John, and Albert A. Rizzo. "Sorting out the Virtual Patient: How to exploit artificial intelligence, game technology and sound educational practices to create engaging role-playing simulations." *International Journal of Gaming and Computer Mediated Simulations* 4, no. 3 (2012): 1-19.

Talen, Emily. "Sustainability." In *The Oxford Handbook of Urban Planning*, edited by Rachel Weber and Randall Crane, 120-140. Oxford, UK: Oxford University Press, 2012.

Talen, Emily, and Cliff Ellis. "Beyond Relativism: Reclaiming the Search for Good City Form." *Journal of Planning Education and Research* 22 (2002): 36-49.

Taylor, Charles. "Invoking Civil Society." In *Philosophical Arguments*, by Charles Taylor, 204-224. Cambridge, MA: Harvard University Press, 1995.

Trimble. "About Trimble: Company History." *Trimble.* 2013. http://www.trimble.com/Corporate/About_History.aspx (accessed February 1, 2014).

U.S. Department of Transportation. "Visualization in Planning." *U.S. Department of Transportation, Federal Highway Administration.* 10 18, 2011. http://www.fhwa.dot.gov/planning/scenario_and_visualization/visualization_in_planning/ (accessed December 15, 2013).

Ungerleider, Neal. "One of America's Largest Hospitals Brings Google Glass into the ER." *Fast Company.* March 21, 2014. http://www.fastcompany.com/3027978/one-of-americas-largest-hospitals-brings-google-glass-into-the-er (accessed March 25, 2014).

United Nations. *World Urbanization Prospects, the 2011 Revision.* Department of Economic and Social Affairs, Population Division, United Nations, Department of Economic and Social Affairs, Population Division, New York, NY: United Nations, 2012.

Unity. "Unity Pro." *Unity.* 2014. https://store.unity3d.com/.

USCICT. *Oculus Rift Development Kit Running PTSD Therapy System.* March 26, 2013.

Ushahidi. *The Ushahidi Platform.* n.d. http://www.ushahidi.com/products/ushahidi-platform (accessed December 2013).

VampireHorde2. "L.A. Noire Hollywoodland Tour Guide Now-And-Then." *IGN.* July 7, 2011. http://ca.ign.com/blogs/vampirehorde2/2011/07/07/l-a-noire-hollywoodland-tour-guide-now-and-then (accessed April 25, 2014).

Ville de Montréal. "Chapter 1: Planning Approach." In *Montréal Master Plan*, 5-8. Montréal, QC: Ville de Montréal, 2004.

—. "Implementation of the administrative reform: Montréal presents optimization workshops led by the new Service de la performance organisationnelle." *Ontario Municipal CAO's Benchmarking Initiative (OMBI).* June 19, 2014. http://www.ombi.ca/wp-content/uploads/Press-release-City-of-Montreal.pdf (accessed August 18, 2014).

—. "Lost neighbourhoods." *Centre d'histoire de Montréal.* n.d. http://ville.montreal.qc.ca/portal/page?_pageid=9077,102008252&_dad=portal&_schema=PORTAL.

Voss, Angi, et al. "Evolution of a participatory GIS." *Computers, Environment and Urban Systems* 28, no. 6 (2004): 635–651.

Wainwright, Oliver. "Work begins on the world's first 3D-printed house." *The Guardian.* March 28, 2014. http://www.theguardian.com/artanddesign/architecture-design-blog/2014/mar/28/work-begins-on-the-worlds-first-3d-printed-house (accessed April 24, 2014).

Wanarata, Konisranukul, and Tuaycharoen Nuanwan. "Using 3D Visualisation to Improve Public Participation in Sustainable Planning Process: Experiences through the Creation of Koh Mudsum Plan, Thailand." *Procedia - Social and Behavioral Sciences* 91 (October 2013): 679–690.

Wang, Shu, Jungwon Min, and Byung K. Yi. "Location based services for mobiles: technologies and standards." *IEEE international conference on communication (ICC).* 2008.

Weber, Samuel. "The Virtual Reality of Theater': Antonin Artaud." In *Theatricality as Medium*, 277-294. New York, NY: Fordham University Press, 2004.

Werner, Franz, Katharina Werner, and Johannes Oberzaucher. "Tablets for Seniors – An Evaluation of a Current Model (iPad)." Edited by Reiner Wichert and Birgid Eberhardt. *Ambient Assisted Living 5: AAL-Kongress 2012 Berlin, Germany, January 24-25, 2012.* Berlin, Germany: Springer, 2012. 177-184.

Wessex Archaeology. "Map of Roman Dorchester - Durnovaria." *Flickr.* July 29, 2011. https://www.flickr.com/photos/wessexarchaeology/5987316664.

Whyte, Jennifer. *Virtual Reality and the Built Environment.* Oxford, UK: Architectural Press, 2002.

Whyte, William Foote. "Introduction." In *Participatory action research*, edited by William Foote Whyte, 7-18. Newbury, CA: Sage Publications, 1991.

Williams, Rhiannon. "Who is already using Google Glass?" *The Telegraph.* April 15, 2014. http://www.telegraph.co.uk/technology/google/10767119/Who-is-already-using-Google-Glass.html (accessed April 16, 2014).

Yao, Richard, Tom Heath, Aaron Davies, Tom Forsyth, Nate Mitchell, and Perry Hoberman. *Oculus VR Best Practices Guide.* v0.008. Oculus VR, Inc., April 30, 2014.

Appendix I: Web-links (complete references in bibliography)

Organizational and Institutional Sites

American Planning Association
https://www.planning.org/

Canada's Action Plan on Open Government
http://data.gc.ca/eng/canadas-action-plan-open-government

Canadian Institute of Planners
http://cip-icu.ca/web/

Center for Interactive Research on Sustainability
http://cirs.ubc.ca/

COLLADA
https://collada.org/

Illinois Simulator Laboratory: CAVE
http://isl.beckman.illinois.edu/Labs/CAVE/CAVE.html

The International Association for Public Participation (IAP2)
http://www.iap2.org/

Museum of London's Streetmuseum
http://www.museumoflondon.org.uk/Resources/app/you-are-here-app/home.html

National Aeronautics and Space Administration, Jet Propulsion Laboratory, Human Interfaces Group
http://www.hi.jpl.nasa.gov/projects/

Open Knowledge Foundation: Open Data – An Introduction
http://okfn.org/opendata/

U.S. Department of Transportation, Federal Highway Administration, Visualization in Planning
http://www.fhwa.dot.gov/planning/scenario_and_visualization/visualization_in_planning/

University of British Columbia, Centre for Interactive Research on Sustainability (CIRS)
http://cirs.ubc.ca/

Ushahidi, The Ushahidi Platform
http://www.ushahidi.com/products/ushahidi-platform

Ville de Montréal, Centre d'histoire de Montréal, Lost Neighbourhoods
http://ville.montreal.qc.ca/portal/page?_pageid=9077,102008252&_dad=portal&_schema=PORTAL

Corporate Sites

Dassault Systèmes, Giza3D
http://giza3d.3ds.com

Eiffage, Phosphore, Visit Marseille in 2030
http://www.eiffage-phosphore.com/visit-marseille-2030

Esri
http://www.esri.com/

IBI Group, Public Outreach
http://www.ibigroup.com/what-we-do/planning/public-outreach/

Pixyul, ReRoll
http://rerollgame.com/

Sony Playstation, inFAMOUS Second Son™
http://us.playstation.com/ps4/games/infamous-second-son-ps4.html

Trimble
http://www.trimble.com/Corporate/

Unity
http://unity3d.com/

Commentary, News, and Press Releases

@Last gets 'Googled'
http://it.tmcnet.com/news/2006/03/15/1460736.htm

@Last Software Announces SketchUp's Sectioning Tool
http://cad.digitalmedianet.com/articles/viewarticle.jsp?id=12339

Angel Flights
http://magazine.ucla.edu/depts/quicktakes/angel-flights/

Are 3D printed houses practical? The experts weigh in
http://www.factor-tech.com/3d-printing/are-3d-printed-houses-practical-the-experts-weigh-in/

Cisco Study Finds Telecommuting Significantly Increases Employee Productivity, Work-Life Flexibility and Job Satisfaction
http://newsroom.cisco.com/dlls/2009/prod_062609.html

Creation Myth
http://www.newyorker.com/reporting/2011/05/16/110516fa_fact_gladwell?currentPage=all

The entire country of Denmark has been recreated in Minecraft
http://www.polygon.com/2014/4/24/5650592/the-entire-country-of-denmark-has-been-recreated-in-minecraft

Drones regulations
http://forums.rerollgame.com/discussion/128/drones-regulations

Film at Expo 67: Canada 67
http://www.yorku.ca/filmexpo/

Ford Taps Oculus Rift For Future Automobile Designs
http://www.fastcompany.com/3024328/innovation-agents/ford-taps-oculus-rift-for-future-automobile-designs

How the L.A. Noire makers re-created the city of 1947
http://articles.latimes.com/2011/apr/24/entertainment/la-ca-noir-city-20110424

History of Sketchup
http://www.mastersketchup.com/history-of-sketchup/

IBM and City of Portland Collaborate to Build a Smarter City
http://www-03.ibm.com/press/us/en/pressrelease/35206.wss

IDG's Macworld Announces Best of Show Awards
http://www.macworld.com/article/1001503/18bestofshow.html

L.A. Noire Hollywoodland Tour Guide Now-And-Then
http://ca.ign.com/blogs/vampirehorde2/2011/07/07/l-a-noire-hollywoodland-tour-guide-now-and-then

Microsoft to acquire Nokia's devices & services business, license Nokia's patents and mapping services
http://www.microsoft.com/en-us/news/press/2013/sep13/09-02announcementpr.aspx

NASA's JPL maneuvers a robot arm with Oculus Rift and Kinect 2, points to more immersive space missions
http://www.engadget.com/2013/12/23/nasa-jpl-control-robotic-arm-kinect-2/

Nokia Maps digitises streets to battle Google's threat
http://www.bbc.com/news/technology-20497719

One of America's Largest Hospitals Brings Google Glass into the ER
http://www.fastcompany.com/3027978/one-of-americas-largest-hospitals-brings-google-glass-into-the-er

Place Making and the Politics of Planning
http://www.slideshare.net/CityRegionStudies/place-making-and-the-politics-of-planning-jennifer-keesmaat

Plan Charlotte: Learning, again, why plans sometimes fail
http://plancharlotte.org/story/charlotte-connect-regional-sustainability-uli-realitycheck

ReRoll story trailer shows off a geographically accurate in-game Montreal
http://www.polygon.com/2014/3/27/5552986/reroll-trailer-video-montreal

Watch Dogs, le très gros budget d'Ubisoft
http://gamers.blogs.challenges.fr/archive/2013/06/18/watch-dogs-le-tres-gros-budget-d-ubisoft.html

Watch Dogs Media Coverage
http://neogaf.com/forum/showpost.php?p=108934587

What Oculus's $2 billion payday teaches us about innovation
http://www.washingtonpost.com/blogs/innovations/wp/2014/03/26/what-oculuss-2-billion-payday-teaches-us-about-innovation/

Who is already using Google Glass?
http://www.telegraph.co.uk/technology/google/10767119/Who-is-already-using-Google-Glass.html

Work begins on the world's first 3D-printed house
http://www.theguardian.com/artanddesign/architecture-design-blog/2014/mar/28/work-begins-on-the-worlds-first-3d-printed-house

Yahoo Issues a Statement on Work-at-Home Ban
http://bits.blogs.nytimes.com/2013/02/26/yahoo-issues-a-statement-on-work-at-home-ban/?_r=0

Yahoo Redux: HP Says "All Hands on Deck" Needed, Requiring Most Employees to Work at the Office (Memo)
http://allthingsd.com/20131008/yahoo-redux-hp-says-all-hands-on-deck-needed-requiring-most-employees-to-work-at-the-office-memo/

Multimedia

3D Models and Environments: Autodesk 123D Gallery, SketchUp 3D Warehouse, etc.

71 E Upper Wacker Dr, Chicago, IL 60601, USA - approximate address
https://maps.google.com/maps?ll=41.887407,-87.625902&spn=0.008083,0.013078&t=h&z=17&layer=c&cbll=41.887152,-87.626309&panoid=opN0ottSGGaqd0n2O4vB_Q&cbp=12,311.75,,0,-1.52

An Old Building in Cork
http://www.123dapp.com/obj-Catch/An-Old-Building-in-Cork/748252

Box house duplex Montreal 01
https://3dwarehouse.sketchup.com/model.html?id=f86249e4d59f775ccca68fa13c76228b

Le Square Phillips Hôtel & Suites
https://3dwarehouse.sketchup.com/model.html?id=2c2f0ec3ffbcd84afac6099f3d4830fe

Rue Notre-Dame ouest, Montréal, QC
https://3dwarehouse.sketchup.com/model.html?id=91334c49de693f48bf78ff333f7ee0b

Flickr Images

2008 09-07 09-08 Dänemark 319 Moens Klint
https://www.flickr.com/photos/wm_archiv/2921100933

Granville and Georgia - 1955/2010
https://www.flickr.com/photos/49576548@N05/5333215127

Map of Roman Dorchester – Durnovaria
https://www.flickr.com/photos/wessexarchaeology/5987316664

Oculus Rift
https://www.flickr.com/photos/chesterbr/11342555355

Oculus Rift: Royal Adelaide Show 2013
https://www.flickr.com/photos/44841911@N07/9932717093

Strollers, seniors, shopping carts & kids - but no curb ramps
https://www.flickr.com/photos/ubrayj02/12621872755

ushahidi en kenya
https://www.flickr.com/photos/ofernandezberrios/3269405041

Woohoo! Free GPS nav from Google
https://www.flickr.com/photos/24652987@N02/4128596089

YouTube Videos

Danmarks frie geodata i en Minecraft-verden
http://www.youtube.com/watch?v=6rMebJWiNUQ

The Future of Design
http://www.youtube.com/watch?v=xNqs_S-zEBY

Infamous: Second Son - Your Questions Answered - The Podcast Beyond Interview
https://www.youtube.com/watch?v=3Ci3rUxWkBs

NASA Robot Arm Control with Kinect
http://www.youtube.com/watch?v=pqNC72fgetc

ReROLL Brick1 Announcement
http://www.youtube.com/watch?v=gGkjm6jD7wU

Scenario 3D: Exploring a Scene
http://www.youtube.com/watch?v=FOxblOb0-zY

Appendix II: General resource of web-links for films and games referenced

Note: There are many other films and games involving virtual reality, planning, and/or models of real urban environments; this is only a list of those titles which have been referenced in this paper.

Films: Internet Movie Database (IMDb)

The Lawnmower Man (1992)
http://www.imdb.com/title/tt0104692/

The Hitchhiker's Guide to the Galaxy (2005)
http://www.imdb.com/title/tt0371724/

Inception (2010)
http://www.imdb.com/title/tt1375666/

The Matrix (1999)
http://www.imdb.com/title/tt0133093/

The Matrix Reloaded (2003)
http://www.imdb.com/title/tt0234215/

The Matrix Revolutions (2003)
http://www.imdb.com/title/tt0242653/

Strange Days (1995)
http://www.imdb.com/title/tt0114558/

The Thirteenth Floor (1999)
http://www.imdb.com/title/tt0139809/

Films using ESRI CityEngine

Man of Steel (2013)
http://www.imdb.com/title/tt0770828/

Total Recall (2012)
http://www.imdb.com/title/tt1386703/

Games: Internet Movie Database (IMDb), Giant Bomb

Driver titles

http://www.giantbomb.com/driver/3025-566/

Driver (1999)
http://www.imdb.com/title/tt0257570/
http://www.giantbomb.com/driver/3030-7020/

Getaway titles

http://www.giantbomb.com/the-getaway/3025-285/

The Getaway (2002)
http://www.imdb.com/title/tt0330323/
http://www.giantbomb.com/the-getaway/3030-1470/

Infamous titles

http://www.giantbomb.com/infamous/3025-1704/

inFAMOUS Second Son (2014)
http://www.imdb.com/title/tt2722728/
http://www.giantbomb.com/infamous-second-son/3030-41695/

True Crime (and related) titles

True Crime: Streets of LA (2003)
http://www.imdb.com/title/tt0378918/
http://www.giantbomb.com/true-crime-streets-of-la/3030-11153/

Sleeping Dogs (2012) (***Note:*** *at one point prior to release, it was titled True Crime: Hong Kong*)
http://www.imdb.com/title/tt2241982/
http://www.giantbomb.com/sleeping-dogs/3030-29441/

Yakuza (*Ryû ga gotoku*) titles

http://www.giantbomb.com/yakuza/3025-766/

Yakuza (Japan: 2005; North America: 2006)
http://www.imdb.com/title/tt0823193/
http://www.giantbomb.com/yakuza/3030-7180/

Yakuza 2 (Japan: 2006; North America: 2008)
http://www.imdb.com/title/tt1275791/
http://www.giantbomb.com/yakuza-2/3030-13147/

Yakuza 3 (Japan: 2009; North America: 2010)
http://www.imdb.com/title/tt1386685/
http://www.giantbomb.com/yakuza-3/3030-22304/

Yakuza 4 (Densetsu wo Tsugumono) (Japan: 2010; North America: 2011)
http://www.imdb.com/title/tt1703112/
http://www.giantbomb.com/yakuza-4/3030-27487/

Ryu ga Gotoku 5: Yume Kanaeshi Mono (Japan: 2012; North America: N/A)
http://www.giantbomb.com/ryu-ga-gotoku-5-yume-kanaeshi-mono/3030-36277/

Other titles

L.A. Noire (2011)
http://www.imdb.com/title/tt1764429/
http://www.giantbomb.com/la-noire/3030-21500/

Watch Dogs (2014)
http://www.imdb.com/title/tt2190152/
http://www.giantbomb.com/watch-dogs/3030-38538/