Towards a spatial imperative in public urban development geovisual analysis and communication

by

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Abstract

Despite advances in GIScience and geovisualization, public consultation for urban development often lack analytical depth or visualization methods that deliver transparent communication and democratic access. Typical methods for engaging the public include the use of architectural designs, artists' renderings, engineering drawings, and physical models (Gill, Lange, Morgan, & Romano, 2013). These methods of urban development communication do little to accommodate portions of the population that are not design-oriented (Al-Kodmany, 1999). This thesis seeks to bridge the gap between GIScience, geovisualization, and urban development through the development of an evaluation framework for existing urban development visualizations. Next, it evaluates visualizations produced for a new development in the District of North Vancouver named "The Residences at Lynn Valley." Following this evaluation, it proposes a set of visibility analyses that aim to reveal the intangible visual impact of future developments. This research provides the basis for future evaluative and analytical work in GIS and geovisualization for urban development.

Keywords: urban development; geovisualization; GIScience; ivosivst; visualization

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List of Acronyms

2D	Two Dimensional
3D	Three Dimensional
AR	Augmented Reality
CAD	Computer Assisted Design
CBO	Community Based Organization
DEM	Digital Elevation Model
DNV	District of North Vancouver
DSM	Digital Surface Model
DTM	Digital Terrain Model
FSR	Floor Space Ratio
GIS	Geographic Information Systems
GIScience	Geographic Information Science
GPS	Global Positioning Systems
LiDAR	Light Detection And Ranging
MLV	Multiple Linked Views
OCP	Official Community Plan
PPA	Preliminary Planning Application
PPGIS	Public Participatory GIS
PPP	Public Participatory Planning
UD	Urban Development
VE	Virtual Environment
VR	Virtual Reality

Chapter 1. Introduction

1.1. Overview

Despite rhetoric trumpeting democratic, transparent public engagement, urban development (UD) is often brokered through privileged close relationships between developers and municipal councils. Although existing decision making processes are nominally democratic, insofar as an elected municipal government determines the pace and form of development, and municipalities are careful to be seen to be conducting public consultation, the extent to which decisions reflect and respond to citizen concerns is highly variable. Urban development is a complex process that occurs between three major stakeholder groups: (1) a municipal council and staff members; (2) developers and their auxiliary staff, such as architects, lawyers, subject expert analysts (e.g. traffic analysts), and public relations staff; and (3) the general public, including affected citizens and local media.

Typical communication methods used during public dialogue include architectural designs, artists' renderings, engineering drawings, and physical models (Gill, Lange, Morgan, & Romano, 2013). This generally involves graphical representations produced by the project's architect from pre-defined vantage points. In his book, <u>Participatory Design: Theory and Techniques</u>, Henry Sanoff (1990) argues that traditional methods of UD communication do nothing to accommodate portions of the population that are not design-oriented (Al-Kodmany, 1999). Representations of the changed built environment are often presented or situated in strategic, flattering or least drastic neighbourhood perspectives. Often, when the development is complete, many local residents are surprised with the final product because they did not have access to exhaustive representations of the project earlier (especially when only basic information and communication is used in public hearing or council meetings). Traditional methods of communication perpetuate the traditional top-down approach to urban development.

1.2. The Research Problem

Emerging types of spatial data, representation and analyses are beginning to provide us with the capability to quantify and visualize a variety of impacts new developments might have on existing neighbourhoods. These powerful forms of analyses enable delivery of meaningful analytical geovisualizations that, in principle, can provide stakeholders with equal access to the scope and implications of proposed development futures. There is both a need, and an opportunity, to communicate the visible and invisible aspects and impacts of proposed developments at all stages of public UD dialogue. Currently, the representations of structural designs remain unnecessarily artistic too far into the process, thus impeding citizens from gaining a full analytical sense of proposals early enough in scheduled municipal dialogue. Spatial analyses are, by academic geographic standards, woefully inadequate, missing, or simplistic. Visualization and communication materials produced at each stage of the process fall well short of what is (easily) possible in the current spatial analysis/geovisualization era. There is little evidence to suggest that municipalities' standards of spatial representation, analysis, and visualization are high enough to adequately support municipal decision-making or public dialogue.

Urban development proposals exhibit varying levels of sophistication, when it comes to spatial representation, impact analysis and visual communication of proposed projects. Urban development should be a democratic process insofar as proposals are approved or rejected by a democratically elected city council. In reality, this process manifests itself with varying levels of openness and privileged information access between council and developers. Effective communication of the impacts on the built environment and surrounding environment is sometimes treated as an afterthought. New ways to enhance access to spatial information, analyses must be identified, if the spatial representation, transparency, and democratic public engagement.

1.3. Research Objectives

The objectives of this research are to explore the way in which geospatial/structural data, representations, and analyses are delivered, communicated, and shared with stakeholders in the urban development consultation process. This research aims to scrutinize existing practices from the perspectives of Geographic Information Science (GIScience), geovisualization, and geovisual analytics. Building upon an evaluation of trends in the research literature, and evidence from focused case studies, this project will explore the importance of spatial information science, spatial analyses, and geovisualizations in urban development dialogue, and how we might democratize access to them.

To address the research challenges outlined above, a set of research questions were identified, organized into the following themes.

Theme 1: Trends in urban geovisualization research

1. Which methods of representation, analysis, and geovisualization are currently used in academic urban development visualization research?

2. Can existing methods be categorized and rated based on the perceived quality of: (1) spatial representation and analysis, (2) visualization quality, (3) communication?

    a. What trends in methods, challenges, and limitations can be identified?

Theme 2: A review of geovisual public engagement from a GIScience perspective

1. How do methods of representation, analysis, and geovisualization manifest in local urban development proposal dialogue in North Vancouver?

2. What are the limitations of existing spatial analytical and geovisual communication practices, and what are their implications?

3. Using GIScience and geovisualization principles, can we prescribe ways to improve spatial representation, analysis, and geovisualization?

    a. Can their capability and potential value be demonstrated?

1.3.1. Thesis Organization

This thesis Is composed of four chapters. Chapter one introduces and contextualizes the research, while chapters 2 and 3 will address my research themes. The conclusion identifies recommendations and a preliminary plan for future research.

Chapters 2 and 3 are written as stand-alone journal articles intended for publication in a peer-reviewed journal.

Chapter 2 aims to: contextualize the use of GIS and data visualization in planning through a brief exploration of relevant literature; propose a framework to guide the evaluation of existing geovisual public participatory planning (PPP) systems; and draw upon our evaluation framework and existing visualizations to suggest the ingredients of preferable PPP visualizations.

Chapter 3 uses GIScience principles to review the District of North Vancouver's (DNV) existing public representations of a development project titled "The Residences at Lynn Valley." Following an in-depth review of existing representations, it proposes and demonstrates a series of visibility analyses that attempt to quantify the development's visual impact on the existing community using industry standard GIS software.

The concluding chapter discusses the significance of the research presented in Chapter 3 and 4, and proposes immediate next steps to further this thesis' research agenda.

1.4. References

Al-Kodmany, K. (1999). Using visualization techniques for enhancing public participation in planning and design: Process, implementation, and evaluation. *Landscape and Urban Planning, 45*(1), 37-45.

Gill, L., Lange, E., Morgan, D. R., & Romano, D. (2013). An analysis of usage of different types of visualisation media within a collaborative planning workshop environment. *Environment and Planning B: Planning and Design, 40*(4), 742-754

Chapter 2. A review of modes of geovisual communication for urban futures in public engagement and dialogue

Introduction

2.1. Introduction

In recent decades, urban planning has seen an ongoing transition from top-down, expert driven systems to a more transparent and bottom-up discourse. The ubiquity and declining costs of computer assisted mapping and design services have given city governments and developers a wide array of tools to perform spatial analysis and visually communicate urban futures to the public. Simply having software tools does not guarantee their effective use. Map outputs and compelling (3D) visuals may or may not deliver adequate or accurate charactererizations of key structural and spatial relationships before or following proposed urban development. These have a fundamental influence on any analyses, interpretations and their communication to the public. In order to effectively contribute to the public participatory planning process, visualization technologies should complement existing social and institutional networks for dialogue between developers, municipalities, and citizens. If these technological and socio-institutional systems are implemented with careful attention to the idiosyncrasies of public participatory planning, they may effectively bridge the gap between stakeholders and provide the basis for productive dialogue.

This paper has four aims: to contextualize the use of GIS and data visualization in planning through a brief exploration of relevant literature; propose a framework to guide the evaluation of both existing and new geovisual public participatory planning (PPP) visualization systems, as well as the sociopolitical systems in which they are used; to present a review of a selected examples of geographic visualization used in the PPP process; and draw upon the evaluation framework and existing visualizations to suggest the ingredients of preferable PPP visualizations. The critical assessment of PPP visualizations results in the creation of two classification and evaluation rubrics. The first rubric will evaluate PPP visualization systems based solely on their visualizations, while the second rubric will evaluate the sociopolitical context in which they are used. The evaluations serve as the starting point for a discussion of the commonalities and differences in current PPP visualization, as well as the traits of an ideal PPP visualization system.

2.2. Public Participatory Planning (PPP)

Public Participatory Planning (PPP) is a sub field of urban planning that focuses on the public's inclusion in planning processes. Scholars have not been able to agree on a consistent definition. Beyea (2009, p. 58) defines it as 'the systematic effort to envision a community's desired future, plan for that future, and involve and harness the specific competencies and inputs of community residents, leaders, and stakeholders in the process." PPP is commonly defined by highlighting its disparity from older, expert-driven approaches. The paradigm shift from top-down planning to PPP was, according to several sources, a response to the undemocratic nature of expert-driven, technocratic systems (Arnstein, 1969; Denhardt and Denhardt, 2000; Laird, 1993; Moote, McClaran, and Chickering, 1997; Briggs, 1998). Top-down systems were common in older modes of public administration. In these "efficient and rational" systems, public administrations were politically neutral and bureaucracies were centralized systems closed to public involvement (Denhardt and Denhardt, 2000). Due to planning's inherent subjectivity, it should not be handled without the public's input.

PPP literature asserts that planning should not proceed without participation from those affected by the decisions because there is intrinsic value in their input (Day, 1997). The idea of PPP is part of the communicative direction urban planning has taken since the positivistic 1960s (McTague and Jakubowski, 2013). However, it is difficult to find a consistent definition of public participation in the theoretical literature (Day, 1997). Schatzow (1977) defines it as the public's direct involvement in decision making through both formal and informal processes. Similarly, Arnstein (1969) describes participation as a method for the inclusion of have-nots in deciding how information is shared, goals and policies are set, tax resources allocated, programs are operated, and how benefits are distributed. In this definition, 'have-nots' refer to those without agency in the urban development process. These two definitions seem similar, but differ in their scope. Schatzow's definition describes how the public must be involved in planning for it to be considered participatory, but it does not clarify who participates. Arnstein's definition serves to clarify who must participate for these processes to be legitimate. Henceforth, this paper will discuss participation as defined by both Schatzow and Arnstein, with emphasis on equal participation from all stakeholders.

In practice, public participation serves two main purposes for planners. The first purpose is to add new information and interpretations of existing data to the planning process, while the second purpose is to ensure all affected stakeholders are informed (Hanna, 2000). In PPP, stakeholders include municipal employees, planners, citizens, developers and their auxiliary staff. Active participation by citizens promotes democracy and restores citizens' faith in the institutions by which they are governed, (Day, 1997; Barber, 1981; Williams, 1976) although it is not guaranteed. When groups that previously held very little power are "activated," it is said to lead to a gradual equalization of power (Day, 1997; Fagence, 1977; Kasperson, 1977). It also serves the purpose of legitimizing municipal decision-making based on the extensiveness of public interaction, and in many places is required by law (Innes and Booher, 2005). Public participation is mainly undertaken through consultation, which includes attitude surveys, neighbourhood meetings, and public hearings (Arnstein, 1969). Consultation allows for citizens to be informed of and have a voice regarding developments. However, there is no guarantee that municipal/developer strategies adequately consider citizen feedback, even if public announcements indicate that all opinions are welcomed. Municipal governments rely on public hearings for discussion, as well as courts to manage disputes and enforce decisions (Bryson and Crosby, 1993).

The focus of this paper's consideration of PPP will be on public meetings, where municipal employees bring together developers and interested citizens for the opportunity to present information and exchange views. Although public participation through consultation is a step in the right direction for communicative planning, there is still room for improvement. Critics of participatory planning do not find problems with the theory behind methodologies, such as public hearings, reviews, and comment processes, but they do not believe PPP methods are being used correctly (Innes and Booher, 2005). The public nature of these sessions caters to the most vocal citizens, who often have the most extreme views that may not align with the less vocal general public (Kingston et al., 2000). Additionally, these meetings often take place in evenings in a location not always accessible to the injured, the disabled, and those without reliable transportation (Kingston et al., 2000). When studying the public consultation process, it is critical to ask who is participating and how they are participating (Hanna, 2000). The exchange of information is a key component to consensus building (Habermas, 1975, 1991; Hanna, 2000). If all stakeholders are not privy to the same information, it delegitimizes the process by exacerbating imbalances of power. In PPP, access to and consideration of all pertinent information is essential for stakeholders to meaningfully contribute to discussion. This includes: adequate communication by developers of the proposed urban projects and their assessments of benefits, impacts and implications; adequate assessment of proposals by municipal councils; and clear communication of the benfits, impacts and implications. In an ideal situation, meaningful public participation and engagement can only take place if all the information is available, accessible, and in a form that the entire proposal can be clearly understood, and responded to.

Unfortunately for citizens, they are not often privy to the same information as the other stakeholders. Municipalities and developers often meet in private to discuss proposals before releasing them to the public, which cultivates a closer relationship of mutual interest. Even if all materials are public, the average citizen does not have enough time nor expertise to familiarize themselves with development proposals (Day, 1997). Citizens' relative lack of familiarity with proposals compared to planners cultivates an image in which citizens are not qualified to make meaningful contributions (Kweit and Kweit, 1999). Even without information asymmetries, there is no guarantee that citizens' opinions will be taken into account by municipalities or developers. Ideally, participation should be a dynamic process that gives all stakeholders a sense of ownership and involvement in the process (McTague and Jakubowski, 2013). Technology plays a significant role in communication among and the exchange of information between stakeholders, which is the foundation for productive participation.

2.3. The role of technology in Public Participatory Planning

Although some degree of public participation is quickly becoming standard practice in planning for urban development, it is not without drawbacks. In a society of individuals with drastically different time constraints, it is not always possible for information to be shared in person. Moreover, stakeholders approach urban development with varying levels of knowledge. Technology can be used to minimize these drawbacks. However, it should be used carefully, as technology has the ability to project a point of view to its audience.

The increasing ubiquity of the Internet has created opportunities for its integration into local democratic processes through online geographic information systems that give citizens access to GIS data and systems with varying levels of sophistication (Kingston et al., 2000). Mapping provides opportunities for collaboration between architects, planners, and GIS professionals because each profession produces and consumes GIS-capable data. Additionally, many GIS and AutoCAD platforms are compatible with their respective data formats, making collaboration more efficient. GIS is indispensable in planning because most information used in policymaking contains map-able information, and stakeholders' increased access is thought to lead to better policymaking (Sieber, 2006). Additionally, maps produced from policy-related spatial data can be used to persuasively convey the importance of ideas more efficiently than text alone (Wood and Fels, 1992). If web GIS is utilized to its potential, it gives citizens access to the information presented at a public hearing while allowing people to present their opinions without the confrontational overtones of most public hearings (Innes and Booher, 2005). While some argue that GIS on its own can guarantee empowerment in local decision-making processes, others argue it is another instrument of capital control and government surveillance (Pickles, 1995; Curry, 1998; Aitken, 2002; Sieber, 2006). This view is both pessimistic and technologically deterministic because it assumes the worst from the social systems in which GIS operates. Despite GIS's institutional origins, public participatory GIS (PPGIS) has been predominantly led by grassroots groups and community based organizations (CBOs) that use it as a tool for capacity building and social change (Sieber, 2006). It is important for both critics and advocates of GIS in planning to view it as a socially constructed technology. Technology is defined as "the knowledge and practices necessary to transform the capabilities of artifacts into useful outputs" (Innes and Simpson, 1993, p. 231). Without the human component, even the most sophisticated technology will not produce meaningful outputs. With this in mind, we consider geovisualization, another field closely associated with GIS, and its ability to translate and communicate abstract spatial analyses effectively to wide stakeholder audiences.

2.4. Geovisualization

In order to facilitate dialogue between all stakeholders, it may be necessary to visually present complex concepts to minimize confusion. Geographic visualization, or geovisualization, is a field in Geographic Information Science that deals with innovative ways to present spatial information to the user. During the 1980s and 1990s, the technological, scientific, and social environments in which maps were produced and used dramatically changed (MacEachren and Kraak, 2001). Researchers acknowledged the limitations of traditional paper maps in favour of more robust electronic methods. These methods enhance spatial learning through: dynamic, sometimes three-dimensional (3D) displays; the use of icons and metaphors in user interfaces; interaction with maps through panning and zooming; integration of multimedia; and separate, integrated views of data (Goodchild, 1992). As with Web GIS, integrated multimedia-GIS frameworks can be used to deliver geographic visualizations to broad audiences (Cartwright et al., 2004). These developments demonstrate a trend towards accessibility to geographic information facilitated by interfaces and mediated by feedback. The convergence of new technologies and methods in mapping has increasingly blurred the boundaries between maps and other form of spatial representation. Geovisualization is a multidisciplinary field that draws on approaches from cartography, scientific visualization, image analysis, information visualization, exploratory data analysis (MacEachren and Kraak, 2001). GIScience provides "theory, methods, and tools for the visual exploration, analysis, synthesis, and presentation of data that contain geographic information" (Dykes et al., 2005). Both have evolved considerably as technology and methods have evolved. Many variable manifestations of spatial representation, analysis and visualization have resulted. And the definition of 'map' has broadened.

The working hypothesis in visualization and scientific computing is that visualizations taking full advantage of the same human cognitive and sensory systems used in the real world are usually the most successful (MacEachren et al., 1999; Dykes et al., 2005; Slocum et al., 2001). Over time, geovisualization has led to the development of an additional field known as "geovisual analytics," which focuses on geographic data exploration through interactive visual interfaces (Chen, Roth, Naito, Lengerich, and MacEachren, 2008; Fabrikant and Lobben, 2009).

Geovisualizations in public urban development dialogue fall into three different categories: (1) non-interactive 2D representations, (2) non-interactive 3D representations, and (3) 2D or 3D interactive geovisualizations. Engineering drawings/schematics, maps, and annotated orthophotos are the most commonly used from category 1, but they may not be useful for the portion of the population who are not design-oriented (Al-Kodmany, 1999). 3D representations (category 2) include artists' or architects' renderings, physical models, or GIS analyses. These include renderings of the area's changed shadow regimes and a number of different visibility analyses. Many 3D visualizations are presented to the user in the form of a snapshot, which does not preserve the visualization's dimensionality due to the display medium's deficiencies. Finally, interactive geovisualizations (category 3) can be either 2D or 3D, and they both allow the user to explore data in a self-guided fashion. Geovisualization principles can be used to enhance users' understanding of geographic data, while PPGIS principles are necessary to inform the optimal method of information exchange between stakeholders.

2.5. Public Participation GIS (PPGIS)

Public participation GIS (PPGIS), as a subfield of GIScience, emerged to explore how GIS technology could support public use of spatial information analysis (Brown and Kytta, 2014; NCGIA 1996a; 1996b; Sieber, 2006). PPGIS has been an established field for some time, having been introduced in 1996 at the National Centre for Geographic Information and Analysis (NCGIA) in the US. As a concept, PPGIS connects its parent disciplines of GIS and public participation. GIS emphasizes spatial technology and information, whereas public participation emphasizes the human and social processes used to include broad audiences in planning, design, and management (Brown and Kytta, 2014). Some critics of GIS have framed it as a return to positivism, while PPGIS scholars have made a concerted effort to situate its use within social processes. Furthermore, to frame GIS as positivist is a reductionist view that ignores aspects of technology, such as practices, laws, organizational arrangements, and the required knowledge for its use (Innes and Simpson, 1993). While GIS is predominantly an expert-driven field, PPGIS seeks to create tools for public interactions with GIS. PPGIS literature considers geospatial collaboration from the perspective of empowerment or mobilization (Bailey and Grosshardt, 2010; Craig, Harris, and Wiener, 2002; Elwood 2002a; 2002b; Ghose and Elwood, 2004). Furthermore, PPGIS focuses on methods for public use of geospatial technologies to participate in local decision-making processes (Tulloch, 2008; Brown and Kytta, 2014). Although the PPGIS literature liberally uses terms like 'public' and 'participation', the definitions of these words are not always consistent about whether the public includes decision makers, implementers, affected individuals, or the random public (i.e. "all the people) (Schlossberg and Shuford, 2005; Brown and Kytta, 2014). Participation has already been defined in Section 2.

In practice, PPGIS research has been guided by the need to identify spatial information potentially useful for planning and decision support, as opposed to conceptual and theoretical development (Brown and Kytta, 2014). GIS use has been furthered by members of the public and private sector who believe access to information is essential in modern democracy (Sieber, 2006). Most PPGIS work has been guided by grassroots groups and community-based organizations (Bailey and Grosshardt, 2010). Participatory mapping requires individuals to remember their experiences in a place, as well as to place those experiences on a map (Brown and Kytta, 2014). It should be used iteratively in the public participatory process, instead of producing a single product (Bailey and Grosshardt, 2010; Brown and Kytta, 2014)

Urban planning is an inherently spatial problem space. Spatial problems contain intangibles difficult to model or quantify, and potential solutions to these problems are often riddled with NIMBYism (Couclelis and Monmonier, 1995; Jankowski et al., 1997). The intangibility of spatial problems leads to controversial outcomes that do not affect all citizens equally. In public urban futures dialogue, spatially intangible problems include Floor Space Ratio (FSR), changes in shadow regimes after the construction of larger buildings, and the prominence of new buildings in a region's skyline. Discussions of externalities are often ungrounded in reality. Since the potential impacts of a new development are not represented visually, discussions often stem from citizens' fears of potential impacts. If combined correctly, geovisualization and PPGIS allow for the creation of relatively unbiased representations to inform productive dialogue. Although all visualizations are subject to the internal biases of their creators, geometry speaks for itself. PPGIS that includes potential impacts help ground the discussion in reality. PPGIS is often used by urban populations, emphasizing the use of spatial data and maps to inform future land use (Brown and Kytta, 2014), though individuals' differing experiences result in conflict views of desirable planning outcomes (Mansourian, Taleai, and Fasihi, 2011). Due to the sometimes unpredictable effects of urban development, planners around the world are making efforts to include citizens in the planning process. GIS has the ability to provide citizens with a way to analytically query and see how proposed redevelopments will change their physical environment; animated and 3D views are considered by many as being particularly effective at communicating these analyses, future scenarios and implications (Al-Kodmany, 2000). Scholars have acknowledged that citizens' knowledge, experience, creativity, and participation are necessary for the creation of acceptable solutions to urban problems (Al-Kodmany, 2000; Jankowski et al., 1997), and that comprehensive urban planning requires personnel with different areas of expertise, while stakeholders bring variable levels and types of knowledge to the process (Mansourian, Taleai, and Fasihi, 2011). GIS is a powerful visualization tool that can be used to proactively prevent misunderstandings when public agencies make changes at the neighbourhood level without consulting residents (Al-Kodmany, 2000). It can be used to translate technical planning language into graphics interpretable by citizens as well as experts. If used responsibly, GIS can provide all stakeholders with an objective and consistent frame of reference for dialogue that links experts knowledge with citizens' insight. GIS can reduce misunderstandings due to information asymmetries. PPGIS as a method to communicate local knowledge which can be used to check and balance expert-driven decisions (Brown, 2012). While 3D geovisualizations allow stakeholders to make sense of multi-faceted spatial issues like urban planning, they can be difficult to disseminate to all interested parties. PPGIS can be used in conjunction with geovisualization to provide information to, and receive feedback from, large audiences.

2.6. Approaching an assessment of geovisual methods: interpretation and evaluation criteria

In participatory planning, GIS and visualization technologies have been used in two general forms. The first involves public participatory web GIS, while the second combines location-based information with 3D geovisualization engines in an attempt to extend traditional maps into the third dimension. PPGIS and geovisualization create opportunities for planners to more effectively include all stakeholders in urban development dialogue, but they need to be applied carefully and methodically for greatest effect. Evaluating multiple examples of geovisual information use in public urban futures dialogue is challenging due to idiosyncrasies in stakeholders, policy context, data, software, training, information design choices, skill and innovation, public engagement strategies of municipal governments. In the following sections, a pair of assessment rubrics are introduced and used to assess geovisual methods in urban futures dialogue.

Due to the socially constructed nature of technology, the evaluation rubric needs to be split into two parts. The first rubric will examine the visualizations themselves, independent of the social landscape in which they are used. The visualization rubric will rate the quality of representation and interactivity of the visualization. Visualizations that score highly in these two categories are more likely to contribute to productive dialogue between all stakeholders (i.e. municipal governments, developers, and citizens). The second evaluation rubric will examine the visualizations in the context of their social landscapes. It will attempt to determine the types and directionalities of communication between stakeholders. While visualizations that score highly in the visualization rubric have the potential to contribute to productive dialogue, they cannot guarantee two-way participation. The effectiveness PPGIS and visualization, like other technologies, depends on the social environments in which they are deployed (Innes and Simpson, 1993). Jankowski and Nyerges (2001) have concluded that user satisfaction with PPGIS systems depended mostly on the presence or absence of a facilitator. If the PPGIS/visualization system allows for detailed feedback from users, the whole effort is in vain if the feedback is not taken into account by developers and the municipality.

2.6.1. Visualization Criterion Group 1: Representation

Representation encompasses how well the visualization in question represents the phenomenon it seeks to emulate. This is arguably the most important evaluation criterion because visualization design strongly impacts a user's worldview (Goodchild, 1992). As previously mentioned, it is pertinent to explore other visualization types besides maps and engineering schematics because they do little for individuals who are not design-oriented (Al-Kodmany, 1999). The transition between 2D and 3D is not straightforward, as the data required for 3D visualizations is more complex. While it is possible to create 2.5D visualizations by extruding 2D data (MacEachren, 1995), they do not capture the intricacies of the building's architecture. 2.5D visualizations involve extrapolating 3D shapes from 2D data (MacEachren, 1995). If presented with a street-level view of a visualization consisting of extruded building footprints, the user's impression area would be closer to Soviet-era block buildings than the area in question. Similar to GIS practitioners' ability to run analyses only at the scale of their coarsest dataset, the dimensionality of the presented visualization is limited by its display medium. If the data itself is 3D, but presented in 2D, the visualization will not likely score highly for quality of representation. This is because the medium with which visualizations are presented should be the same as the visualization itself. If a 3D visualization is presented as a set of 2D snapshots, the user no longer gains many of the benefits of 3D visualizations, such as the ability to change the vantage point. Each visualization's dimensionality will be evaluated based on its dimensionality at the stages of phenomenon conceptualization, data capture, representation, and visualization (Hedley and Aagesen, unpublished). A visualization's representation score is partially based on whether the dimensionality of the input data, analyses, and final visualizations match the phenomenon.

Visualizations can be broadly classified as aesthetic or analytical. Aesthetic visualizations are designed to be visually appealing and to give stakeholders a sense of the aesthetics of new buildings. They are usually created by the project's architect and present an idealized version of the development devoid of undesirable aspects, which include (but are not limited to) poor weather, dirty streets, or traffic congestion that often follows densification. Analytical renderings are less common than artistic renderings. They aim to reveal the intangible externality effects of urban development that don't become apparent until the development is built. Additionally, analytical visualizations can be used to visualize abstract concepts like Floor Space Ratio (the ratio between the floor area of a building and the size of the lot on which it is constructed). Well-designed analytical visualizations can provide the basis for productive dialogue about externalities in which all participants have access to relevant, understandable visual information. Furthermore, visualizations can be viewed from either a bird's eye view or a perspective that matches the way people experience the world. A bird's eye view allows users to explore how new developments fit into the broader context of the area, while a human perspective allows people to experience the new developments in a manner that mimics their everyday, lived experience. No single visualization type is inherently *better* than another, but the overall quality of representation is likely to increase if a wide variety of types are used. The availability of a wide range of visualizations gives stakeholders the opportunity to enrich their understanding. A visualization with high representation quality requires well thought out interactivity in order reach its potential.

This paper's evaluation framework does not solely derive a visualization's quality of representation based on its dimensionality and analytical or aesthetic nature. A series of five representational characteristics shown to increase a visualization's potential for information transfer have been extracted from the relevant literature. They include dynamism, dynamic re-expression, real time rendering, multi-resolution rendering, and the dimensionality of the display used to present the visualization. Dynamic visualizations change in real time in response to the user's actions (Andrienko and Andrienko, 1999; Wood et al., 2005). The use of 3D environments increases the potential for dynamism in visualizations, while high-quality real-time rendering allows users to explore interactive virtual environments that simulate urban futures (Wood et al., 2007). Highly interactive 3D visualizations often utilize virtual environments (VEs), which refer to a digital environment designed to simulate the real world (Wang, 2002). Dynamic re-expression is a technique that changes the way data is visualized to support knowledge construction (Andrienko and Andrienko, 1999; Keim, Panse, and Sips, 2005). A 2D example of dynamic re-expression is using both a choropleth and graduated symbol map to present the same phenomenon. It is important to include a range of visualization methods to appeal to a broader audience. Real time rendering is necessary to facilitate proper dynamism in the visualization (Dollner, 2005; Bodum, 2005). The lack of real time rendering limits interactivity because every scene presented to the user must be created in advance. The goal of urban development geovisualizations should be to allow free form exploration of urban futures instead of a constrained experience with only pre-defined vantage points. Multi-resolution rendering involves storing 3D objects at different levels of detail. Objects close to the observer are rendered in full detail, while objects further away are rendered with less detail to reduce computational overload, which increases the smoothness of the visualization (Dollner, 2005; Keim, Panse, and Sips, 2005; Wood et al., 2005). While multi-resolution rendering is not always necessary, it can be implemented to maintain visual fidelity while maximizing the number of devices potentially able to display the visualization. Finally, it is important to consider the dimensionality of the display used to present the visualization. There is a fundamental disconnect between the 2D representations often used to represent urban development and the way people experience the real world, which is fundamentally three dimensional. While 2D maps successfully provide the broader geographic context for urban development, it is impossible to convey its impact without utilizing the third dimension. While representational characteristics are necessary to properly communicate the impacts of potential urban development, they are wasted without proper interactivity methods.

2.6.2. Visualization Criterion Group 2: Interactivity

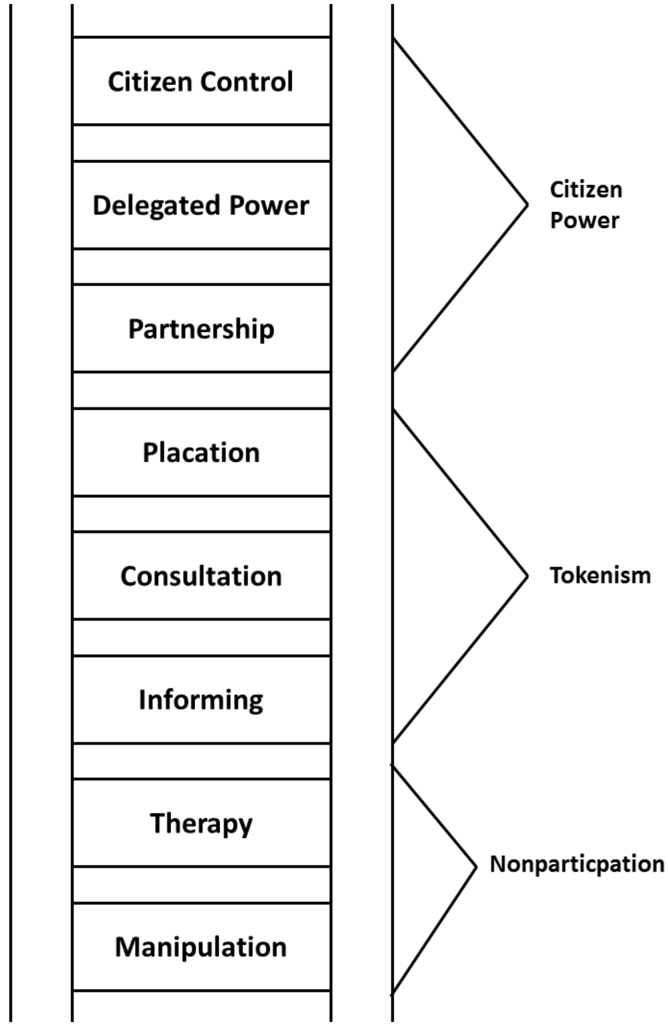
"Interactivity" is the second criterion grouping in this evaluation. This section of the evaluation seeks to reveal which visualizations include viewpoint/position control, interaction with objects, brushing, highlighting, zooming, and multiple linked views. These interactivity features have been well established in data visualization literature to make knowledge transfer more efficient. This includes the degree to which the visualization is static or dynamic, as well as how much control the user has over what they see. The first, and arguably the most important, interactivity characteristic is full viewpoint and position control for the user. Allowing users to change their viewpoint and position is a step towards the use of visualizations that take full advantage of the same human cognitive and sensory systems used in the real world, which are the most successful (MacEachren et al., 1999). Some visualizations give the user the illusion of interactivity by allowing them to switch between a set of pre-defined viewpoints. Granted, this is better than no interactivity at all, but it is not an adequate substitute for giving users freedom to choose their own vantage points. To keep the user's attention, it is critical for virtual objects in the visualization to be interactive (MacEachren et al., 1999; Slocum, 2009; Dykes, MacEachren, and Kraak, 2005). Without interactive objects, the visualization is less likely to keep the user's attention once the initial "wow" factor wears off.

As previously mentioned, increasingly complex 3D datasets require more sophisticated methods of interaction, including multiple linked views (MLV), zooming, highlighting, and brushing (Keim, 2005; Roberts, 2005; Cartwright et al., 2004; Gahegan, 2005; Keim, 2005). MLV is the concurrent use of two different views of the same dataset to give the user context and assist with sense-making and allow them to compare different properties of the data (Roberts, 2005; Andrienko and Andrienko, 1999). MLV is often used concurrently with brushing, highlighting, and zooming. The use of MLV has been shown to increase users' knowledge construction by freeing up the user's working memory (Roberts, 2005; Ware and Plumlee, 2005; North and Schneiderman, 2000). In geographic applications, MLV is most commonly implemented by including a smaller-scale inset map that shows the visualization's study area in the context of the broader geographic landscape. For example, an inset map will highlight the area shown by the larger-scale visualization. Brushing is the act of highlighting the same portion of data on each linked view (Cartwright, Miller, and Pettit, 2004). It is part of a broader set of tools, including MLV, highlighting, and zooming, that allows users to dynamically alter the visualization to better suit their objective (Keim, Panse, and Sips, 2005). A consequence of focusing the user's attention on individual areas is that they lose the context of the surrounding landscape (Buja et al., 1991). This is where the combination of brushing and MLVs serves to give the user a clear look at the local changes in their environment, while maintaining the context of a broader landscape. Highlighting is used in combination with MLV and brushing to mark corresponding sections on different displays with the same colour (Andrienko and Andrienko, 1999; Keim, Panse, and Sips, 2005; Roberts, 2005). Zooming is most often used for interactive 2D maps, but can also be used in 3D virtual environments to dynamically alter the user's view and facilitate knowledge transfer (Keim, Panse, and Sips, 2005). Each visualization's interactivity score will incorporate the degree of freedom it grants the user to explore the visualization. Each representational and interactivity characteristic is recorded in the evaluation as either present or absent. While the technological side of urban development communication is important, one cannot ignore the socio-institutional arrangements between stakeholders.

2.6.3. Communicative directionalities between stakeholders

Technology alone is not enough to adequately ensure all stakeholders' opinions are heard, but it can be used to facilitate the process. Urban development involves interactions between agents of municipal governments, developers, and affected citizens. Participatory planning requires some degree of communication between each stakeholder group, which can have many possible directionalities (Figure 2). The directionalities of communication can be compared to Arnstein's (1969) ladder of citizen participation (Figure 1).

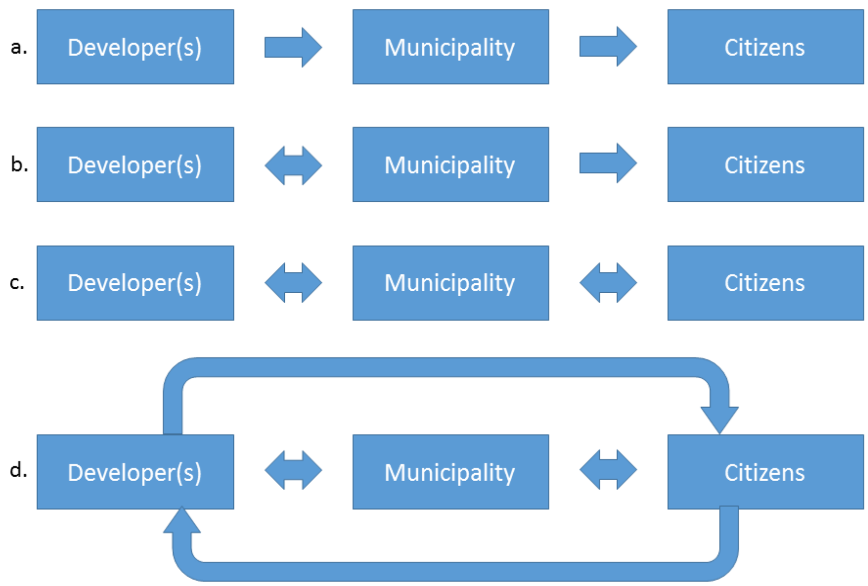
Figure 1 The ladder of citizen participation



Note: Adapted from Arnstein (1969)

In Arnstein's classification, citizens' involvement in the planning process ranges from manipulation, where citizens support is engineered by the municipality, to citizen control, where residents are given full control of policy and management (Arnstein, 1969). Communicative directionalities from Figure 2a and 2b are representative of either manipulation, therapy, or informing. Arnstein (1969) acknowledges that although informing involves the use of citizen questionnaires, there is no guarantee that the developer or municipality will listen to the advice. Although Figure 2b shows two-way communication between developers and municipalities, communication between municipalities and citizens is still one way. The directionality of communication Figure 2c denotes two-way interaction between developers and municipalities, as well as between municipalities and citizens. In this situation, the municipal government is the mediating party between developers and citizens, but there is little to no direct communication between them. Based solely on the directionality of communication, once would expect Figure 2c to equate to either consultation or placation. Consultation refers to public participation done through attitude surveys, neighbourhood meetings, or public hearings; it is a step towards full participation, but it must be combined with other modes (Arnstein, 1969). Placation is one step above consultation because it involves picking citizens for advisory committees (Arnstein, 1969). Finally, Figure 2d refers to directionalities expected from either partnership, delegated power, or citizen control. Delegated power and citizen control involve providing citizens with more power than the government or developers to make decisions that affect their community. This degree of participation has been dismissed by academics and professionals as ineffectual. Yang et al. (2011) suggest there are tradeoffs between participant competence and representativeness for citizen participants. In this case, partnership, which involves the redistribution of power through negotiation between citizens and powerholders, strikes an ideal communicative balance between all stakeholders (Arnstein, 1969). Despite the importance of communicative directionalities, the visualizations selected for evaluation have been evaluated at a distance. This distance has made a proper assessment of communicative dimensionalities impossible, as few papers discuss how their visualization systems were used. In the few cases described, there is not enough information to make an assessment. However, communicative directionalities are a crucial component of urban futures dialogue.

Figure 2. Communicative Directionalities Between Stakeholders

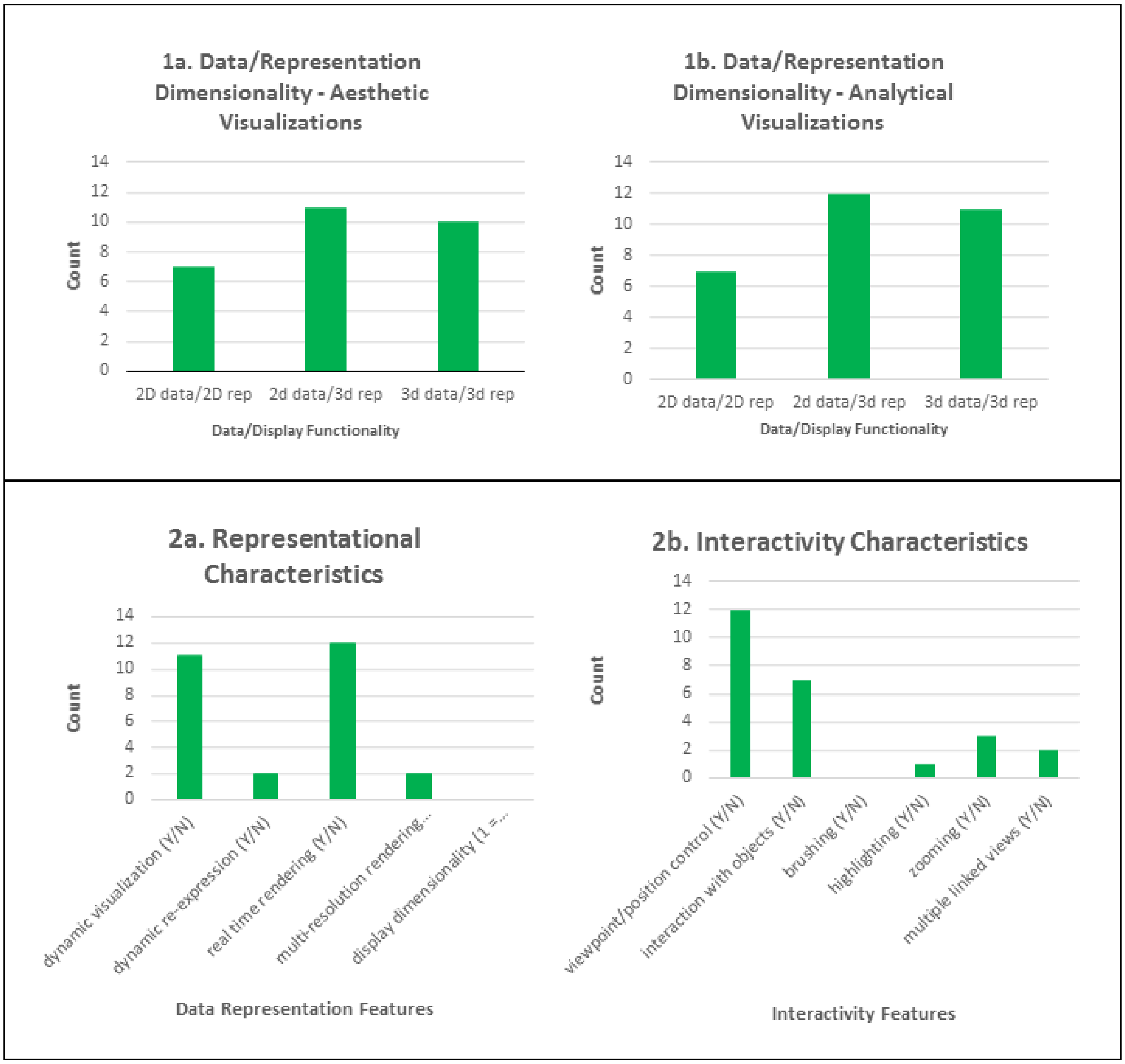


2.7. Discussion

2.7.1. Representational and Interactivity Characteristics at-a-glance

Out of the 20 urban development and landscape planning visualizations surveyed, 70% were aesthetic, while the remaining 30% were analytical. Until quite recently, topologically 3D GIS analyses have not been included with industry standard software suites. However, ESRI's ArcGIS has built in functions for topologically 3D shadow and viewscape analysis. Future urban development visualizations should aim to incorporate topologically 3D analysis as it becomes increasingly accessible in the future. Figure 2 contains a high-level summary of the evaluation results.

Figure 3. Summary of Evaluation Results



An examination of the evaluation results for representational characteristics reveals surprising results (Figure 2). Counterintuitively, more visualizations make use real time rendering (12 of 20) than are considered dynamic (11 of 20). While real time rendering is required for interactive virtual environments, it does not guarantee dynamism. In order for visualizations to be considered dynamic, their content must change (i.e. instead of only the viewpoint changing) due to the user's actions. While a slight majority of visualizations are dynamic, very few employ dynamic re-expression. In other words, there are no alternative visualizations to appeal to a broader audience. However, there were more aesthetic visualizations, leaving fewer opportunities to employ dynamic re-expression. Although a majority of visualizations used real-time rendering, only two make use of multi-resolution rendering. One possible explanation is the authors did not include it in their articles. The papers often left out technical details in favour of a phenomenological approach, electing to describe how their systems fit into the rezoning process instead. Further explanation requires deeper probing of the data, which will be covered in subsequent sections. The last representational feature covered by the evaluation is display dimensionality. Every visualization used a 2D display instead of a 3D display. Although 3D, head-mounted displays (HMDs) are becoming cheaper and easier to implement than in the past, public consultation is often done on a very small budget. Additionally, because HMDs meant for use by individuals. The idea behind public participation is to include as many participants as possible, which makes HMDs logistically incompatible with the process. To fully harness the effectiveness of a visualization, strong interactivity features must complement its representational prowess.

Figure 2 contains a summary of interactivity characteristics of visualizations across all dimensionalities. The lack of brushing (0 of 20), highlighting (1 of 20), and MLV (2 of 20) may be explained by the lack of analytical visualizations. Aesthetic visualizations are less likely to use these interactivity methods, except for the inclusion of an inset map to show the user's location. The analytical visualizations' lack brushing, highlighting, or MLV may have been a conscious decision by the developers to avoid confusing their audience with too many interface options. However, these concerns are not necessarily valid. It is possible to design interfaces with intuitive basic tools as well as more in-depth tools for advanced users. The relative lack of zooming (3 of 20) is likely explained by a lack of 2D visualizations. As an interaction method, zooming is primarily utilized by 2D interactive maps and does not translate well to 3D virtual environments. This can be attributed to the relative complexity of navigating in three dimensions as opposed to navigating in two dimensions. Despite lacking other interactivity characteristics, a majority (12 of 20) visualizations included viewpoint and position control. Aesthetic and analytical visualizations alike benefit from giving the user full control over their viewpoint. Interaction with objects (7 of 20) was not as common as viewpoint and position control, but more common than the other factors. A visualization's dimensionality can have an impact on the effectiveness of certain representational or interactivity characteristics.

2.7.2. Dimensionality

The combination of 2D input data and 3D representation is most common among both analytical and aesthetic visualizations. This is unsurprising, as a vast majority of GIS data exists in 2D. Furthermore, the creation of fully featured 3D models is a long and tedious process for those without proper training. Not only is creation an issue, but detailed 3D models often have large file sizes and are computationally intensive to render. The least common dimensionality is 2D input data and 2D representation, which is likely due to a sampling bias towards 3D visualizations. Yet, his category also encompasses 3D visualizations with 2D elements, of which there are very few. Although 3D visualizations provide the user with an experience that may closely match their lived experience in real space, wayfinding can be an issue in virtual environments (Chen and Stanney, 1999). In order to address the wayfinding issue, many 3D virtual environments give the user a 2D map to pinpoint their location in the broader geographical context. In a virtual environment, it is possible to know the user's location to the precision of a single pixel. Unlike GPS in the real world, it is possible to know the user's exact coordinates in a virtual world.

2D input data and 2D representation

Of the 10 aesthetic and analytical visualizations that use 2D data and 2D representation, very few make use of the representational characteristics described in section 2.6.1 or the interactivity features described in section 2.6.2. From the representation assessment, the most commonly identified feature was real time rendering (3 of 10), followed by dynamism and dynamic re-expression (2 of 10 for each). While 2D web maps, for example, are often rendered on the fly, the evaluation's definition of real time rendering pertains to 3D graphics. The examples of real time rendering seen here are most likely from 3D visualizations that use 2D elements. The lack of dynamism is likely because a majority of the 2D examples were not presented on a computer. By definition, paper maps cannot be dynamic. Furthermore, dynamic re-expression is not possible on paper for the same reasons as dynamism. Furthermore, there is only one example of multi-resolution rendering. Again, because display dimensionalities were not mutually exclusive, this example is from the visualization's 3D portion.

From the interactivity assessment, the most common features are viewpoint and position control (3 or 10) and interaction with objects (3 of 10). The lack of interactivity features is largely due to the lack of computerized examples. Full viewpoint and position control means different things for 2D and 3D visualizations. 2D visualizations use simpler controls while giving the user less freedom, while 3D visualizations have more complex controls, giving them more freedom to choose their desired viewpoint.

2D input data and 3D representation

Of all the visualizations, 17 include 3D depictions of 2D data (2.5D), making it the most common type of dimensionality. This is likely due to the ubiquity of 2D data, as well as our sampling bias towards 3D visualizations. 2D geographic data is currently more common than 3D data. Additionally, GIScientists recognize the usefulness of 3D visualizations for representing a phenomenon like urban development. The combination of data availability and the desire to present information in 3D makes the 2.5D majority unsurprising. The two most common representational characteristics are dynamism (10 of 17) and real time rendering (12 or 17). While real time rendering theoretically allows for free form exploration of the dataset, it does not guarantee dynamism. Few examples employ dynamic re-expression (2 of 17), although one could argue the extrusion of 2D into the third dimension is itself an example of dynamic re-expression. However, examples like this were not recorded that way because the user does not have the option to toggle between 2D and 3D views of the same dataset. Multi-resolution rendering was only used in 3 of 17 visualizations. This is not surprising, as 2.5D data is less geometrically complex than a topologically 3D model, which makes multi-resolution rendering unnecessary.

12 of 17 examples included full viewpoint and position control, which is to be expected since programs designed to view 3D data have built in controls to manipulate the viewpoint. Every visualization using real time rendering also included full viewpoint and position control. However, only 8 examples allow the user to interact with virtual objects. While 3D data viewers often have intuitive controls to manipulate the dataset, they are less likely to allow the user to interact with the objects on a deeper level. 2D GIS allows the user to query discrete objects, but there has traditionally been a disconnect between 2D GIS and 3D visualization platforms. While transferring geometry between

platforms is relatively low effort, the same cannot be said about the database connections that querying possible. Any querying of objects in a 3D non-geographic 3D environment must be programmed by the visualization designer. Brushing (0 of 17), highlighting (1 of 17), zooming (3 of 17), and multiple linked views (4 of 17) are relatively underutilized. One possible explanation is that while most commercial GIS software has these capabilities to some degree, they are inaccessible to non-experts. Integrating these interaction methods into systems for use by non-experts requires sophisticated interaction design and coding, which makes the visualization system more difficult and expensive to produce. Public consultation is usually done on a tight budget, making these kinds of initiatives unappealing.

3D input data and 3D representation

A total of 13 of 20 visualizations include both 3D input data and 3D representation. The number is lower than 2D data and 3D representation because 3D input data is less commonly available. However, there is more 3D data available for urban development because building architects design their buildings using modelling software that produces formats interoperable with other 3D viewers. The distribution of representational and interactivity features are similar enough to visualizations with 2D input data and 3D representation. There are a few possible reasons for this. In many cases, 3D visualizations use a combination of 2D and 3D input data, meaning the same visualization will be counted twice. The most surprising similarity between the two is the lack of multi-resolution rendering. While 2.5D geometry is simple enough that multi-resolution rendering is not required, the same cannot be said for many 3D models. The most obvious reason for the lack of multi-resolution rendering is the 3D models did not have a level of detail to make it necessary. Furthermore, creating multiple models of the same object is a tedious and time consuming task that was likely not deemed worth the effort. In other cases, the areas under consideration were not large enough to necessitate multiple levels of detail. The distribution of interactivity characteristics does not differ enough from 2D data and 3D representation to warrant a second discussion.

2.7.3. Limitations of the effectiveness of visualization in public dialogue

Despite this paper's focus on visualization, it should be noted that improved visualizations alone do not fix existing issues in the public consultation process. Visualizations are merely a small part of a complex, socio-institutional process like urban development. A visualization's effectiveness is strongly dependent on the objectivity of its creator. Most often, visualizations are produced either by the developer or the municipal government, with the occasional partnership with a university/research institution. Without a neutral third party, there is a risk that developers or municipalities will design visualizations that intentionally distort or ignore less favourable aspects of potential developments. Due to the complexity of creating intuitive, interactive 3D visualizations, there is no guarantee that a visualization will bridge the knowledge gap between planners, developers, and the average citizen. Additionally, even if visualization systems effectively bridge the knowledge gap between stakeholders, there is no guarantee that citizen feedback will be incorporated into the project. To cynics, public consultation is merely tokenism on the part of developers and municipalities. That is, municipalities and developers merely want to be *seen* consulting with citizens, but do not intend to act on their feedback.

As noted by Kinston et al. (2000), citizens often lack the free time necessary to physically show up at public hearings. Additionally, public hearings tend to cater to the most vocal citizens, who often have the most polarizing views (Kingston et al., 2000). To cater to the busy and the timid, researchers have developed online tools to visualize potential developments while curating citizens' feedback. However, online tools must strike a balance between visual fidelity and accessibility. As visualizations become more detailed, the number of devices able to render them falls. Furthermore, online-only visualizations risk alienating citizens who are less comfortable with unguided use of technology. Visualizations need to be carefully designed to provide adequate freedom to allow users to explore the virtual developments at their own pace. Designers must also limit users' freedom to ensure the interface does not obfuscate information transfer. Improvements to public geovisual communication is only one part of the larger research agenda for improving the public consultation process.

2.8. Conclusions

As cities continue to densify, conflicting views of urban futures have been, and will continue to be, major points of contention between citizens, municipal governments, and developers. The ubiquity and declining costs of GIS and computers opens a wide array of options for urban futures communication. Visualizations have a fundamental influence on public perception of rezoning projects, so they must be designed carefully. They augment, rather than replace, existing socio-institutional networks for dialogue amongst stakeholders. Technology does not exist in a vacuum; rather, it is inextricably linked to the socio-institutional systems in which it is used – a fact underscored by GIScientists (see Chrisman, 1996). This evaluation framework is the first step towards systematically assessing the potential effectiveness of various visualization systems in practice.

The evaluation rubric's representational and interactivity metrics were selected based on empirical evidence from the geovisualization literature of their effectiveness in maximizing knowledge transfer. An evaluation of 20 examples of urban futures visualizations revealed that the most common representational characteristics, regardless of dimensionality, are dynamism and real-time rendering. Both of these characteristics are possible with a wide range of 3D data viewers and require little to no extra training for implementation. The most common interactivity characteristics were viewpoint and position control, along with interaction with objects. While viewpoint and position controls are built into every 3D viewer, interaction with objects is often more difficult to implement. The least common representational characteristics were dynamic re-expression, multi-resolution rendering, and 3D display dimensionality. Dynamic re-expression and multi-resolution rendering can be difficult to implement due to the extra time required for their implementation, while cost was likely the largest factor limiting 3D displays.

While the evaluation is a step in the right direction, it is not without its limitations. Its main limitation is how it can only evaluate each visualization based on what the authors present or report in their papers. Another limitation is the relatively small number (20) of visualizations selected for evaluation. The examples were chosen based on a set of search keywords, including 'visualization', 'public participation', 'GIS', 'urban development', and 'urban planning.' Initially there were 30, but the authors did not provide enough information about the visualizations in their papers to complete the evaluation. There are relatively few examples of urban futures visualizations in the literature, so a portion of the final 20 examples focused more broadly on landscape planning as opposed to urban futures. Our review revealed a bias towards 3D visualizations in the academic literature. One possible explanation stems from the scope of our search, where we sought studies that focused on the use of visualizations in public participation, rather than all examples of GIS in public participation. Our research has revealed that in visualization research, there is a clear bias towards 3D visualizations.

Future work in visualizing urban futures for dialogue should take two directions. One avenue of future work should involve a more in-depth look at fewer examples to ascertain visualizations' impact on existing socio-institutional dialogue networks. A study like this would require interviews with representatives from all three stakeholder groups and full access to all visualizations. Another option for future work is the development of our own visualization system that carefully incorporates all representational and interactivity characteristics from this evaluation.

2.9. References

Aitken, S. (2002). Public participation, technological discourses and the scale of GIS. *Community Participation and Geographic Information Systems,* 357-366.

Al-Kodmany, K. (1999). Using visualization techniques for enhancing public participation in planning and design: Process, implementation, and evaluation. *Landscape and Urban Planning, 45*(1), 37-45.

Al-Kodmany, K. (2000). GIS in the urban landscape: Reconfiguring neighbourhood planning and design processes. *Landscape Research, 25*(1), 5-28.

Arnstein, S. R. (1969). A ladder of citizen participation. *Journal of the American Institute of Planners, 35*(4), 216-224.

Barber, D. M. (1981). *Citizen participation in american communities: Strategies for success* Kendall/Hunt Publishing Company.

Briggs, X. (1998). Doing democracy up-close: Culture, power, and communication in community building. *Journal of Planning Education and Research, 18*(1), 1-13.

Brown, G. (2012). Public participation GIS (PPGIS) for regional and environmental planning: Reflections on a decade of empirical research. *URISA Journal, 24*(2), 7-18.

Brown, G., & Kyttä, M. (2014). Key issues and research priorities for public participation GIS (PPGIS): A synthesis based on empirical research. *Applied Geography, 46*, 122-136.

Bryson, J. M., & Crosby, B. C. (1993). Policy planning and the design and use of forums, arenas, and courts. *Environment and Planning B, 20*, 175-175.

Buja, A., McDonald, J. A., Michalak, J., & Stuetzle, W. (1991). Interactive data visualization using focusing and linking. Paper presented at the *Visualization, 1991. Visualization'91, Proceedings., IEEE Conference on,* pp. 156-163, 419.

Bunch, R. L., & Lloyd, R. E. (2006). The cognitive load of geographic information. *The Professional Geographer, 58*(2), 209-220.

Cartwright, W., Miller, S., & Pettit, C. (2004). Geographical visualization: Past, present and future development. *Journal of Spatial Science, 49*(1), 25-36.

Chen, J., Roth, R. E., Naito, A. T., Lengerich, E. J., & MacEachren, A. M. (2008). Geovisual analytics to enhance spatial scan statistic interpretation: An analysis of US cervical cancer mortality. *International Journal of Health Geographics, 7*(1), 57.

Curry, M. (1998). *Digital places: Living with geographic information technologies* Routledge.

Day, D. (1997). Citizen participation in the planning process: An essentially contested concept? *Journal of Planning Literature, 11*(3), 421-434.

Denhardt, R. B., & Denhardt, J. V. (2000). The new public service: Serving rather than steering. *Public Administration Review,* , 549-559.

Dykes, J., MacEachren, A., & Kraak, M. -. (2005). Exploring geovisualization. In J. Dykes, A. M. MacEachren & M. -. Kraak (Eds.), *Exploring geovisualization* (1st ed., pp. 1-19) Pergamon.

Fabrikant, S. I., & Lobben, A. (2009). Introduction: Cognitive issues in geographic information visualization. *Cartographica: The International Journal for Geographic Information and Geovisualization, 44*(3), 139-143.

Fagence, M. (1977). *Citizen participation in planning* Elsevier.

Gahegan, M. (2005). Beyond tools: Visual support for the entire process of GIScience. In J. Dykes, A. M. MacEachren & M. J. Kraak (Eds.), *Exploring geovisualization* (pp. 83-99). Amsterdam ; San Diego: Elsevier.

Gill, L., Lange, E., Morgan, D. R., & Romano, D. (2013). An analysis of usage of different types of visualisation media within a collaborative planning workshop environment. *Environment and Planning B: Planning and Design, 40*(4), 742-754.

Goodchild, M. F. (1992). Geographical information science. *International Journal of Geographical Information Systems, 6*(1), 31-45.

Goodchild, M. F. (1999). Cartographic futures on a digital earth. Paper presented at the *Proceedings of the 19th International Cartographic Conference,* pp. 4-12.

Greenwood, P., Sago, J., Richmond, S., & Chau, V. (2009). Using game engine technology to create real-time interactive environments to assist in planning and visual assessment for infrastructure. *Proceedings MODSIM.Cairns,*

Habermas, J. (1975). *Legitimation crisis* Beacon Press.

Habermas, J., & McCarthy, T. (1991). Communication and the evolution of society.

Hanna, K. S. (2000). The paradox of participation and the hidden role of information: A case study. *Journal of the American Planning Association, 66*(4), 398-410.

Herrlich, M. (2007). A tool for landscape architecture based on computer game technology. Paper presented at the *Artificial Reality and Telexistence, 17th International Conference on,* pp. 264-268.

Innes, J. E., & Booher, D. E. (2004). Reframing public participation: Strategies for the 21st century. *Planning Theory & Practice, 5*(4), 419-436.

Innes, J. E., & Simpson, D. M. (1993). Implementing GIS for planning lessons from the history of technological innovation. *Journal of the American Planning Association, 59*(2), 230-236.

Jankowski, P., Nyerges, T. L., Smith, A., Moore, T., & Horvath, E. (1997). Spatial group choice: A SDSS tool for collaborative spatial decisionmaking. *International Journal of Geographical Information Science, 11*(6), 577-602.

Jeong, J. S., Hernández-Blanco, J., & García-Moruno, L. (2014). Approaches to validating a mutual participatory web-planning interface in rural extremadura (spain). *Land use Policy, 39*, 211-223.

Kasperson, R. E. (1977). Participation through centrally planned social change: Lessons from the american experience on the urban scene. *Public Participation in Planning,* , 173-190.

Keim, D. (2005). Information visualization: Scope, techniques, and opportunities for geovisualization. *Exploring geovisualization* (1st ed., pp. 23). Amsterdam ; San Diego: Elsevier.

Kingston, R., Carver, S., Evans, A., & Turton, I. (2000). Web-based public participation geographical information systems: An aid to local environmental decision-making. *Computers, Environment and Urban Systems, 24*(2), 109-125.

Kweit, R. W., & Kweit, M. G. (1999). *People & politics in urban america* Routledge.

Laird, F. N. (1993). Participatory analysis, democracy, and technological decision making. *Science, Technology & Human Values, 18*(3), 341-361.

Lonergan, C., & Hedley, N. (2015). Navigating the future of tsunami risk communication: Using dimensionality, interactivity and situatedness to interface with society. *Natural Hazards,* , 1-23.

Lonergan, C., Hedley, N., & Clague, J. J. (2015). A visibility-based assessment of tsunami evacuation signs in seaside, oregon. *Natural Hazards,* , 1-19.

MacEachren, A. M., Edsall, R., Haug, D., Baxter, R., Otto, G., Masters, R., et al. (1999). Virtual environments for geographic visualization: Potential and challenges. Paper presented at the *Proceedings of the 1999 Workshop on New Paradigms in Information Visualization and Manipulation in Conjunction with the Eighth ACM Internation Conference on Information and Knowledge Management,* pp. 35-40.

MacEachren, A. M., & Kraak, M. (1997). Exploratory cartographic visualization: Advancing the agenda. *Computers & Geosciences, 23*(4), 335-343.

MacEachren, A. M., & Kraak, M. (2001). Research challenges in geovisualization. *Cartography and Geographic Information Science, 28*(1), 3-12.

MacEachren, A. M. (1995). GVIS: Facilitating visual thinking. In A. M. MacEachren (Ed.), *How maps work: Representation, visualization, and design* (pp. 513). New York: Guilford Press.

Mansourian, A., Taleai, M., & Fasihi, A. (2011). A web-based spatial decision support system to enhance public participation in urban planning processes. *Journal of Spatial Science, 56*(2), 269-282.

McTague, C., & Jakubowski, S. (2013). Marching to the beat of a silent drum: Wasted consensus-building and failed neighborhood participatory planning. *Applied Geography, 44*, 182-191.

Moote, M. A., McClaran, M. P., & Chickering, D. K. (1997). Theory in practice: Applying participatory democracy theory to public land planning. *Environmental Management, 21*(6), 877-889.

Morgan, E., Gill, L., Lange, E., & Romano, D. (2009). Rapid prototyping of urban river corridors using 3D interactive, real-time graphics. *Peer Reviewed Proceedings of Digital Landscape Architecture 2010 at Anhalt University of Applied Sciences,* , 182-190.

O'Coill, C., & Doughty, M. (2004). Computer game technology as a tool for participatory design.

Pickles, J. (1995). *Ground truth: The social implications of geographic information systems* Guilford Press.

Roberts, J. (2005). Exploratory visualization with multiple linked views. In J. Dykes, A. M. MacEachren & M. J. Kraak (Eds.), *Exploring geovisualization* (1st ed., pp. 159-180). Amsterdam ; San Diego: Elsevier.

Schatzow, S. (1977). The influence of the public on federal environmental decisionmaking in canada. *Public Participation in Planning.London: John Wiley,*

Schlossberg, M., & Shuford, E. (2005). Delineating" public" and" participation" in PPGIS.

Sieber, R. (2006). Public participation geographic information systems: A literature review and framework. *Annals of the Association of American Geographers, 96*(3), 491-507.

Tulloch, D. (2008). Public participation GIS (PPGIS). In K. Kemp (Ed.), *Encyclopedia of geographic information science* (pp. 352-355)

Williams, S. H. (1976). Citizen participation in city and regional planning: An effective methodology. *Town Planning Review, 47*(4), 349.

Wood, D., & Fels, J. (1992). *The power of maps* Guilford Press.

Wood, J., Dykes, J., Slingsby, A., & Clarke, K. (2007). Interactive visual exploration of a large spatio-temporal dataset: Reflections on a geovisualization mashup. *Visualization and Computer Graphics, IEEE Transactions on, 13*(6), 1176-1183.

Chapter 3. The use of spatial data and visualization in DNV urban development consultation process: present and future

3.1. Introduction

In 2011, the District of North Vancouver (DNV) city council ratified its Official Community Plan (OCP). The document acknowledges that the region was expected to grow by approximately 40,000 residents by 2013 (DNV OCP, 2011). The region predominantly consists of single family dwellings, which comprised 56.1% of the district's housing stock (Census Canada, 2011). In order to preserve its single family neighbourhoods, city council decided to concentrate growth in a network of dense growth centres interspersed with low-density housing (DNV OCP, 2011). To deal with population growth, the DNV has implemented policies to contain growth and development in existing built areas (DNC OCP, 2011). Despite the district's public consultation work, densification efforts have been met with controversy. Public hearings for new development proposals have been riddled with controversy and confusion regarding new developments. Proposals can be difficult to compare because visualizations are not consistent across developments. Additionally, there are no publicly available GIS representations of potential impacts to the existing built environment.

This chapter will explore how GIScience principles can be used to enhance the DNV's online representation of urban futures. To accomplish this goal, it will first describe how GIS and visualization tools have been used in practice to visually communicate urban development in North Vancouver. The first question is whether data and resulting analyses have been made public. Most importantly, do existing visualizations capture the externalities of new developments? Externalities include increases in shadowing and changes to existing residents' views. Next, the paper will look at ways to use available data and GIS tools to improve the communication of urban futures in the DNV, using the development called "The Residences at Lynn Valley" (which will be henceforth referred to as "The Residences") as the study area. This involves using GIS to facilitate understanding by incorporating strategies that cater to the different ways people learn most effectively.

3.2. Public input and visualization in the District of North Vancouver's Rezoning Application Procedure

The goal of this paper is not to redefine the DNV's rezoning process, but to optimize the use of GIS visualizations within it. The District provides information to the public at three stages of the process: (1) The pre-application process, (2) rezoning application procedure, and (3) public information meetings (Rezoning Application Procedure, 2011). In the pre-application process, developers must produce a Prelminary Planning Application (PPA) to receive comments from DNV staff, the local Community Association, and neighbours adjacent to the property. The PPA itself is not released to the public, although citizens are free to view it through a freedom of information request. However, this process can be rather lengthy (our request took about 4 weeks to fill) due to government departments' existing workloads.

Figure 4 Side-view of The Residences

Note: This image was created by BOSA for a public hearing. Photo by the author.

The PPA for The Residences includes a mixture of loosely connected textual information, maps, annotated aerial photos (both orthographic and oblique), images of existing buildings, and digital renderings of the proposed buildings (Figure 4). The initial pages of the document contain both renderings of the proposed project, as well as images of the existing area. The project is situated by a site description page that contains a textual description of the development's location accompanied by an annotated aerial photo. The combination of text and images on this page do well to situate the development within the existing community for those with pre-existing knowledge of the area. The PPA also includes a project rationale statement, which begins with describing the area in its current form and goes on to specify what the developers believe to be the future impacts and benefits of the development. However, the benefits and impacts are presented in point form with little accompanying detail. Additionally, they do not acknowledge the impacts the new developments will have on existing residents' views.

Based on feedback from stakeholders, the developer decides whether to develop a more detailed application. If the developer decides to continue, they are subject to the rezoning application procedure. In this phase, signs are placed on the property to be rezoned, and residents within 75 metres must be notified by mail (DNV Public Notification Policy #8-3060-3). Additionally, the developer must provide the following materials to the district: a site plan with the building's location and parking layout, floor plans, building elevations, landscape concept plans, a summary of the colours and materials, and 8½ reduced plans for staff support and neighbourhood plans (Rezoning Application Procedure, 2011). The notification rules for public information meetings are similar to the rezoning application procedure. Prior to the meeting, developers must deliver an information package to residents, business, and property owners within 75 metres, and to the president of the area's Community Association. Additionally, they must post a sign on the property to be developed and advertise the meeting in two issues of a local newspaper. At this point, the District provides many of these materials on their website for consumption by a larger audience. The next section will review the DNV's current online informational materials for ongoing rezoning proposals as of October 2015.

3.3. A review of the District of North Vancouver's online representation of new developments

The aim of this section is to describe the methods used by DNV to inform citizens of rezoning applications through their website. Emphasis is placed in online representations because they are the most accessible way for citizens to inform themselves of potential changes to their neighbourhoods. Additionally, the online materials provide the same information as the posters available at public consultation sessions. The online materials utilize a combination of text descriptions and static, two dimensional visualizations.

Text descriptions are used to describe the location of the project, building size, current and future zoning information, the project's background, and potential changes to surrounding streets. Each project's webpage identifies the project's location by naming the nearest cross streets. While these descriptions are adequate for those with intimate knowledge of the district, they may be difficult for newer residents to understand. Building sizes are illustrated by the number of storeys, but not in metres. There are no comparisons to the heights of existing buildings to provide further context. Additionally, the floor area of buildings is given using Floor Space Ratio (FSR), which is a fractional number comparing the floor area of the proposed building with the area of its lot. Zoning information is presented using DNV zoning bylaw language. Changes to surrounding streets are also expressed through textual descriptions that describe locations relative to existing streets and the building lot. While these descriptions may be comprehensible to planners, architects, and developers, the average citizen is unlikely to benefit as much as experts would from information presented in this manner. Furthermore, the text descriptions are very loosely (if at all) linked with the visualizations available on the website.

Visualizations of development sites are a mixture of maps and fixed perspective 3D representations. However, the types of visualizations are not consistent across all examples. Some contain high quality architectural renderings that include the surrounding area, while others only include simpler artists' sketches that do not include the surrounding area for context. Map formats include hand drawn approximations, highly detailed engineering or planning schematics, and annotated aerial photos. Maps are used inconsistently across all examples. Some do not include maps at all, while others use only planners' reference maps. None of the maps show the development's location in the context of DNV as a whole. This is unlikely to present any issues to long time residents, but it could potentially alienate newer residents. In one case (Mountain Village), a 2D map uses colour coded building footprints to show building heights. While the map indisputably contains all necessary information about building heights, it is not presented in an intuitive manner. A 3D visualization would allow the same information to be presented in a way that allows viewers to instantly connect the representation with their lived experience. Furthermore, planning and engineering schematics present the viewer with more information than needed, which increases the amount of mental effort required to extract meaning from visualizations. This is otherwise known as cognitive load (Bunch and Lloyd, 2006). Perspective 3D visualizations are more likely to trigger the same human cognitive and sensory systems as in the real world, and are more likely to efficiently disseminate information (MacEachren et al., 1999).

DNV makes use of artists' illustrations and photorealistic architectural renderings to augment their text descriptions and 2D maps. However, each only present the view from pre-defined vantage points, which leaves open the possibility of bias towards the developer by showing the most aesthetically pleasing views, while hiding the least flattering. Furthermore, the ground locations and heights of each viewpoint are not explicit, which may cause confusion. If the viewpoints are not taken from ground level, the may misrepresent the impacts that new developments will have on the area's spatial character. Focusing on individual viewpoints, while necessary, only conveys partial information about the area (Andrienko and Andrienko, 1999; Buja et al., 1996). The 3D perspective visualizations would be less ambiguous if they were linked to a 2D map showing the location and direction of each viewpoint. While the 3D perspective visualizations are generally of high quality, their ability to present information suffers due to their disjoint with 2D maps.

Figure 5 Loosely linked text and image

Site overview

The site is

- located in the Lynn Valley Town Centre and includes the site of the former Zellers store, the parking structure facing Mountain Highway and the former District Library site at 1280 East 27th Street
- approximately 4.8 acres (1.93 hectares)

Site layout: Select to view larger version

Current zoning

This site has been rezoned to Comprehensive Development Zone 80 (CD80).

The proposed development is in accordance with the objectives for Lynn Valley Town Centre in the District's Official Community Plan (OCP) and the "flexible planning framework" for Lynn Valley Town Centre adopted by District Council on October 7, 2013.

Proposed size

The floor space ratio proposed is approximately 2.36 over the area of the site under redevelopment. (Floor Space Ratio, or FSR, is the ratio of the building area, divided by the site area – a 10,000 square foot building sitting on a site of 10,000 square feet has a Floor Space Ratio of 1.0).

Heights of the six building proposed range from four storeys to 12 storeys.

Access

New roadways are proposed at the east and west sides of the proposed development, in accordance with the planning objectives for Lynn Valley Town Centre.

Note: This page can be accessed at: http://www.dnv.org/property-and-development/1175-lynn-valley-road-and-1280-east-27th-street

The redevelopment information webpages amass a wide variety of often loosely linked textual and visual information (Figure 5). While visuals and text are presented on the same page, no explicit connections are made between the two. To maximize the flow of information, Bunch and Lloyd (2006) advocate for the use of text explicitly linked to visuals. Additionally, the pages focus on the developments to the point that they largely ignore the surrounding area. We see this as a flaw in the way information about potential developments has been presented to the citizenry. Those who own property in the surrounding area are mainly interested in how the new developments will affect them. In section 4, we will discuss conventional GIS methods for analyzing the impact of potential developments on the visibility characteristics of the surrounding area.

3.4. Citizen-centric GIS analysis of new developments

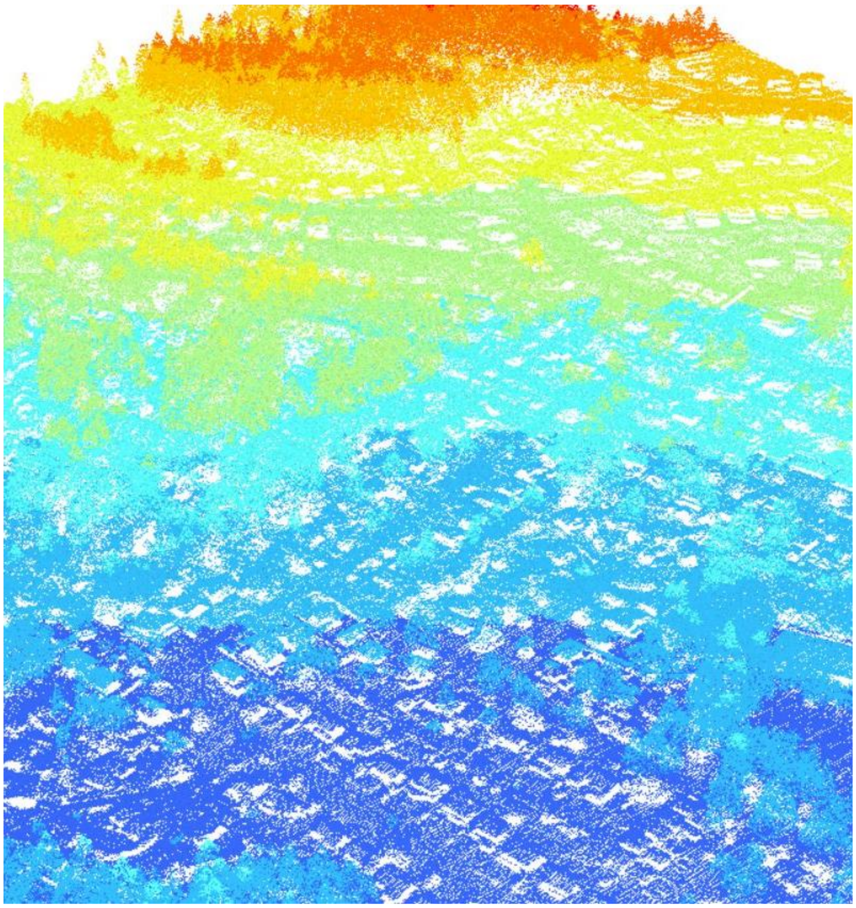
3.4.1. Introduction to GIS visibility analysis

Visibility analysis allows us to predict the visual impact of potential developments before they are built, which would provide citizens with the information they deserve during the public consultation process. Industry standard GIS software packages have robust tools to measure visibility. The visualscape, as defined by Llobera (2003, p. 30) as "the spatial representation of any visual property generated by, or associated with, a spatial configuration." To unpack this definition, a spatial representation describes the way the visual property of a location is stored and represented. A visual property can be described as any 'visual characteristic' of one's study area. Finally, spatial configuration refers to how one selects the spatial components that make up their area of interest (Llobera, 2003). In the context of this study, the spatial configuration includes all surface features (natural and constructed) in the community surrounding The Residences. The visual property we are examining is the amount of terrain visible from set locations both before and after development. The visual property we are interested in has been discussed previously in the literature using the term *isovist*. Isovists can be defined as location-specific patterns of visibility (Benedikt, 1979). Location-specific patterns of visibility are influenced by a region's topography, as well as the presence or absence of other barriers to visibility. The dominant barriers to visibility differ between urban and rural areas.

Previous visibility research has been separated by urban and rural study areas because the primary barriers to visibility are different in each context. Urban landscapes have used Benedikt's (1979) interpretation and definition of isovists, while visibility in the context of the natural environment have been described using the term "viewshed" (Bartie et al., 2010; Llobera, 2003). In its most basic form, a viewshed describes intervisibility between points (Fisher, 1991). If two points are within one another's line of sight, they are said to be intervisible. Viewsheds determine the visibile landscape from observer points by determining areas in which a straight, uninterrupted line can be drawn between the two points (Llobera, 2003). Although isovists and viewsheds are both used to describe visibility, some scholars consider them separate concepts. Weitkamp (2011) describes isovists as a representation of the space that can be 'overviewed', and viewsheds as a representation of surface visibility. Morello and Ratti (2009, p. 839) have also defined isovists as "the field of view available from a fixed point of view." Functionally, the difference between the two definitions is minimal. In order for a surface to be visible, the space between the observer and the object must be overviewed. The terms 'viewshed' and 'isovist' will be used interchangeably due to their degree of interrelatedness. Additionally, GIS visibility analyses utilize concepts from both viewsheds and isovists to generate visualscapes.

In practice, visibility analyses are often fraught with inadequate input data and are limited by the dimensionality of existing algorithms. Input data issues include potential errors in the DEM, and a lack of detailed land coverage like vegetation or the built environment (Llobera, 2003). The most common barriers to visibility in urban environments include buildings, billboards, trees, and bushes, which are not accounted for in most elevation models. However, the land coverage issue is solved by high resolution point cloud data from LiDAR sensors (Figure 6) or SFM (structure from motion) modeling. Although isovists have been a subject of theoretical discussion for decades, true 3D visibility analysis is rare due to the 3D limitations of GIS and the lack of GIS functionality in CAD systems (Engel and Dollner, 2009). The proliferation of LiDAR datasets that capture both topography and the built environment vastly increases the accuracy of visibility assessments (May, Ross, and Bayer, 2005; Bartie et al., 2010). It is now possible to determine a potential development's visual dominance, landmark clarity, as well as its highest and lowest visibile points. Morello and Ratti (2009) have worked to develop a 3D isovist theory, where DEMs are used to incorporate topography and the built environment (Bartie et al., 2010). Furthermore, it is possible to use Llobera's (2003) visual exposure models to determine the portion of a feature visible from the surrounding space (Bartie et al., 2010).

Figure 6 **Visual representation of raw LiDAR data of the District of North Vancouver**



To fully understand isovists, it is critical to discuss their geometries. Isovist geometries are often discussed with reference to their origin and target. The origin is the viewpoint of the observer, while the target is the object being observed. Isovists can either be constrained or panoptic (Lonergan and Hedley, 2015). Panoptic isovists are a representation of the space potentially visible to an observer in a specific location, while a constrained isovist can take humans' limited field of view into account. Both origin and target isovists can have multiple geometries, which include points, lines, areas, and volumes. Point-origin, panoptic isovists are a representation of the space visible to an observer in a fixed location, regardless of their direction. Conversely, a point-origin constrained isovist would represent the space visible to an observer facing a specified direction. Line-origin isovists (Figure 7) can be used to describe the space visible to an observer along a path, such as a sidewalk or road. This type of isovist can be used to quantify a road or trail's spatial openness, which is "the volume of the part of a surrounding sphere which is visible from a given point of view" (Morello and Ratti, 2009). It represents a location's openness to natural light, air, and distant views, and has been equated to the concept of "perceived density" (Morello and Ratti, 2009). Area-origin isovists represent the visible space from a surface, such as a building's façade. While point, line, and area origin isovists are relatively easy to conceptualize, their implementation in a GIS environment is not straightforward.

Figure 7 A representation of the space visible from the street

Visibility algorithms in existing GISs can only calculate visibility from a point source. Lines and areas must be split into evenly spaced points before visibility algorithms can be applied. Additionally, the input data's dimensionality impacts the visibility analysis' accuracy. Most terrain data contain one elevation point for each Cartesian coordinate. Visibility analyses that use this type of terrain model is known as 2.5D because each geographic coordinate only has one elevation value. For large, natural landscapes, this limitation does not often cause a drastic reduction in accuracy. However, issues arise in urban areas due to the complexity of the built environment, especially when dealing with bridges or other overhanging structures (Lonergan and Hedley, 2015; Yang, Putra, and Li, 2007). Areas under overhanging structures will incorrectly be considered obstructions. The proliferation of LiDAR and emergency of structure from motion (SFM) modelling in recent years opens up a wide range of possibilities for visibility analysis using topologically 3D datasets. Unlike their 2.5D counterparts, 3D visibility analyses will correctly interpret the space under overhanging buildings as a non-barrier to visibility.

While 3D analyses are more accurate, they are also more difficult to accomplish. Topologically 3D datasets often begin as large point clouds that cannot be analyzed without extensive pre-processing. Many GISs can automatically create terrain models from point clouds, although this process results in a 2.5D dataset. Another option would be to procedurally generate a 3D sphere for each data point. However, this method is prohibitive due to the computational resources necessary to create, store, and analyze millions of 3D objects. The ideal method for analyzing topologically 3D data would be to create a virtual environment with LiDAR-derived terrain, and a set of 3D models that accurately represents the study area's urban built environment. However, manually generating 3D models for even a moderately sized urban environment can be excessively time consuming. As procedural 3D modeling continues to improve, it will open up opportunities for scalable, programmatic 3D virtual environment generation.

3.4.2. GIS Visibility Analyses

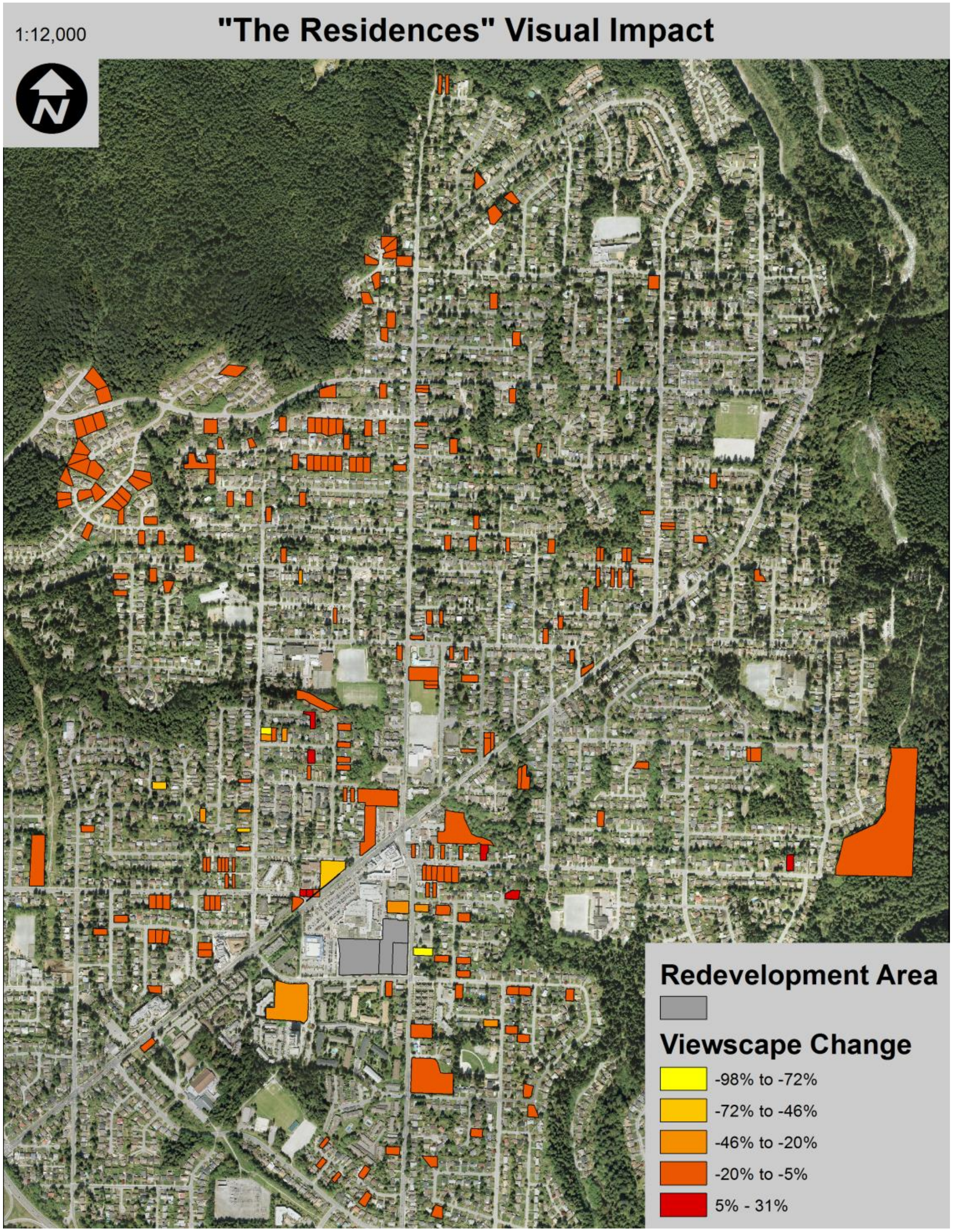
Despite the limitations of 2.5D analysis, the following GIS analyses have been completed using 2.5D viewshed analysis in ArcGIS. The size and granularity of the input LiDAR data makes the implementation of topologically 3D analysis impractical due to the size of the study area. The input LiDAR data has a spatial resolution of one point every ~0.9m, excluding edge datasets, which were excluded from the analysis. The point clouds were converted to a digital surface model (DSM) with 1m spatial resolution. Despite the issues with overhanging buildings, we opted to use a DSM for the visibility analysis due to the reduced computational overhead. Additionally, the study area contains no bridges and few overhanging structures. For this study, we determined the increased computational efficiency justifies a minor reduction in accuracy. In public information sessions, existing residents have expressed concerns regarding uncertainties of the visual impact new developments will have. The analyses outlined below aim to quantify and visualize what is otherwise intangible until the developments in question are built. The first visibility analysis quantifies The Residences' visual impact on existing property parcels, the second quantifies the developments' relative visual prominence, and the third quantifies the spatial openness of three main roadways surrounding The Residences before and after development. For each isovist calculation, we developed scripts using ArcPy (ESRI, 2016) to programmatically generate a point-source viewshed, save it to memory to reduce processing time, and record the number of visible raster cells. Each point's viewshed is an example of a point-origin to area isovist (Lonergan and Hedley, 2015). This result was then joined with the original shapefile for visualization.

Quantifying the impact of new developments on existing properties

The goal of this analysis is to quantify changes to existing residences' viewscapes caused by The Residences. The centroid of each property parcel polygon is the origin of a point-source, panoptic isovist, which is implemented in ArcGIS using its built-in viewshed algorithm (ESRI, 2016). The input surface model is a combination of a fully-featured digital terrain model (DTM) generated from LiDAR, and of a regional DEM with 30m resolution. GIS best practices for combining surface models of different resolutions normally involve reducing the resolution of the finer surface model to match that of the lower resolution. However, in order to combine the DTM and DEM, the DEM was resampled to 1m resolution. This was done to take residents' views of the surrounding landscape into account while preserving the LiDAR's high spatial resolution. If we had resampled the 1m DSM to 30m, we would not have been able to adequately represent The Residences' geometry. Furthermore, all viewshed origins are well within the LiDAR extent, so we can expect closer features to have the greatest impact on visibility.

Results

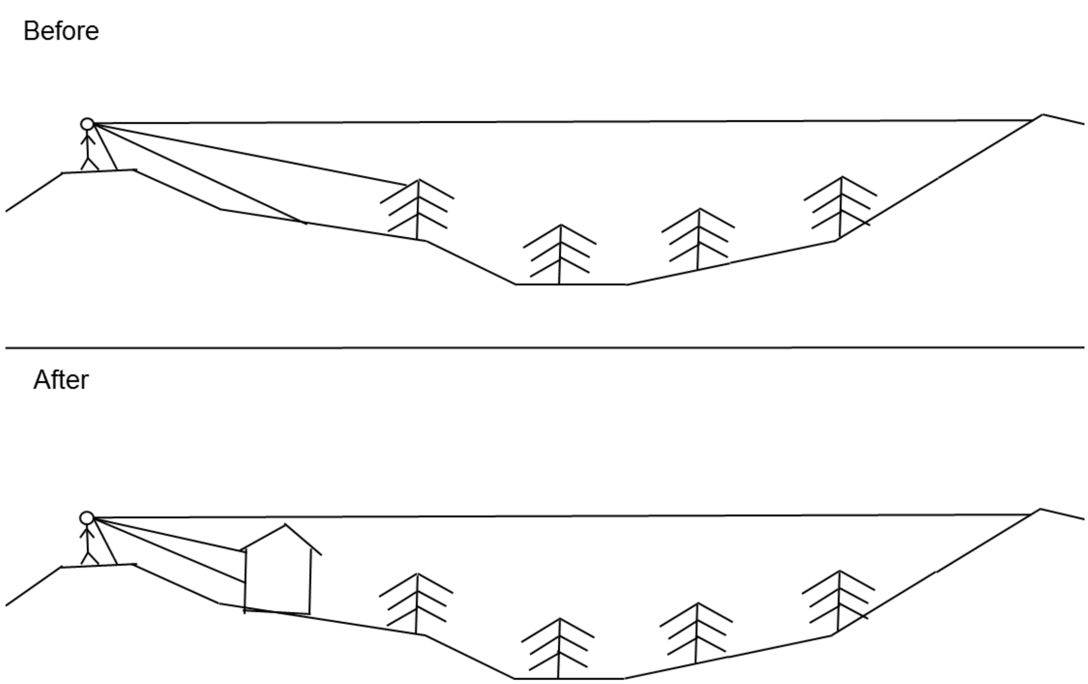
Figure 8 The Residences Visual Impact



Note: Aerial photo was obtained from the DNV Geoweb (http://www.geoweb.dnv.org/)

The visual impact analysis has revealed a wide range of impacts to existing parcels' viewscapes. The impacts range from a ~30% increase in visible area to a 90% reduction in visible area. In general, there is a greater reduction in the amount of visible landscape in areas closer to the development, which we expected. However, less properties were affected than we expected. Out of approximately 4800 parcels in the immediate area, only 251 were affected. North Vancouver as a whole has an abundance of trees and bushes, which limits the extent of residents' viewscapes more than new developments. One of the most common fears articulated by citizens at public hearings and information sessions regarding the visual impact of new developments on the viewscapes of existing property owners. For a majority of properties, these fears are unfounded. If this analysis had been performed prior to public consultation, it is very likely that it would have focused dialogue and mitigated many citizens' fears. However, for the affected minority, this would have been cause for concern. It is important to note that the view from each parcel was calculated from a single point. More detailed analyses can be done for the most severely affected properties to determine the extent of view loss. While our output map is able to show The Residences' visual impact on all 251 property parcels, it does not reveal the inner mechanics of visibility analyses.

Figure 9. Visibility Analysis Conceptual Diagram



The Residences' visual prominence

The visual prominence analysis involves generating area-origin isovists from The Residences' façades to identify which portions are most visible to the surrounding community. As previously mentioned, ArcGIS's visibility analysis algorithms are limited to point-origin isovists. To generate area-origin isovists, we first digitized The Residences' building footprints based on materials provided at public information sessions. Next, we converted the building footprints into a 3D grid of points spaced 1m apart and used them as inputs for viewshed analysis. Although the inputs are a series of points, their aggregate is an area-origin isovist for each of The Residences' façades. The combination of façade isovists results in a volume-origin isovist, which is consistent with the isovist typology proposed by Lonergan and Hedley (2015). The viewsheds' input surface model is the LiDAR-derived DSM described in section 4.2.1 without the regional DEM. The regional DEM was not included because we are only concerned about the development's visibility from North Vancouver.

Results

Figure 10. The Residences Visual Prominence

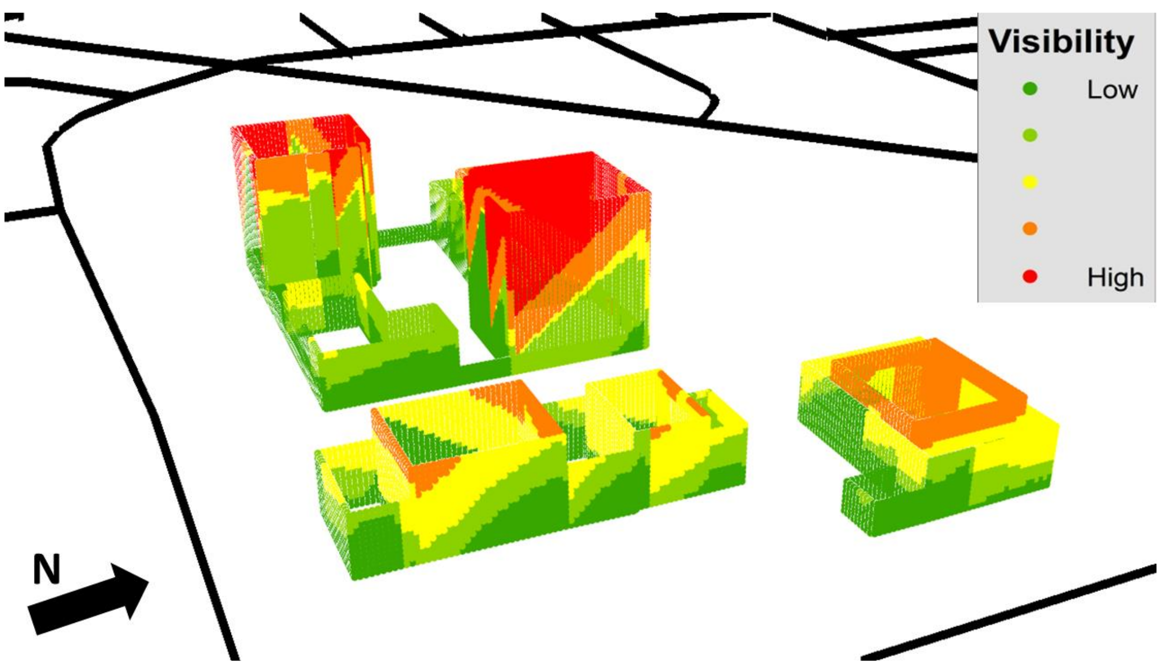
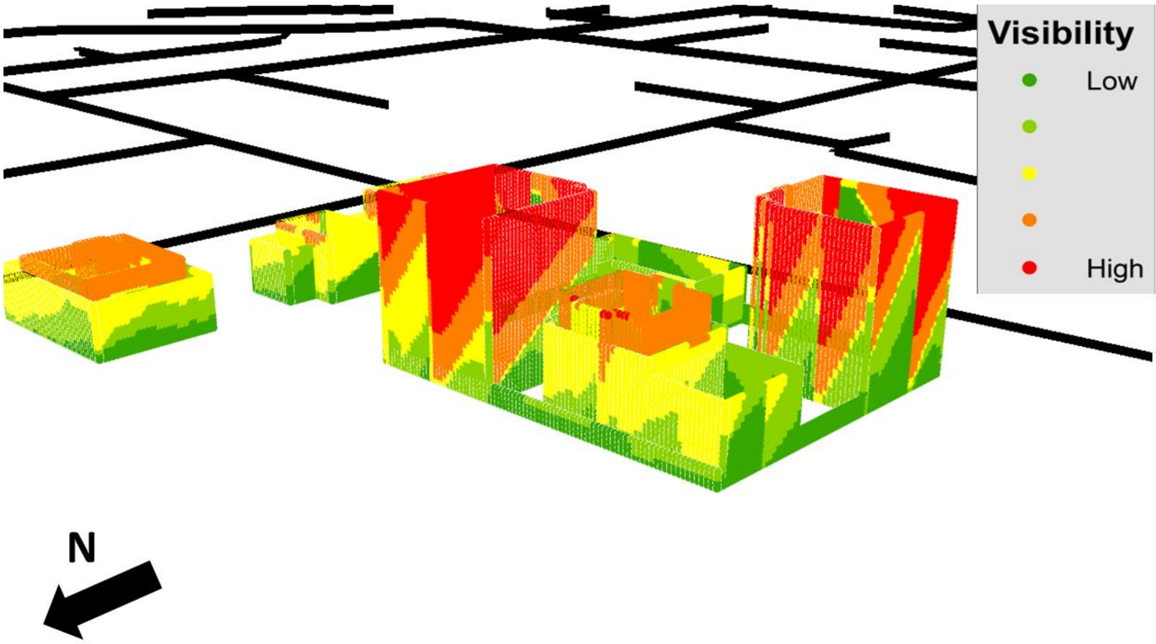


Figure 11. The Residences Visual Prominence



The results of this analysis as shown in figures 4 and 5 are not at all surprising, as higher portions of each building are more visible than the base. Out of the three analyses, the visual prominence is the least useful for public dialogue, as it is focused on the development itself, instead of its effects on the surrounding area. However, potential homebuyers would be interested in seeing which units are more private than others. Additionally, this analysis shows which units can see more of the surrounding landscape. Sections of the building that are deemed less private also have superior views of the surrounding landscape. Analyses of this nature can be incorporated into property appraisals, as both privacy and views can be incorporated into the value of a home.

Quantifying The Residences' impact on surrounding roadways' spatial openness

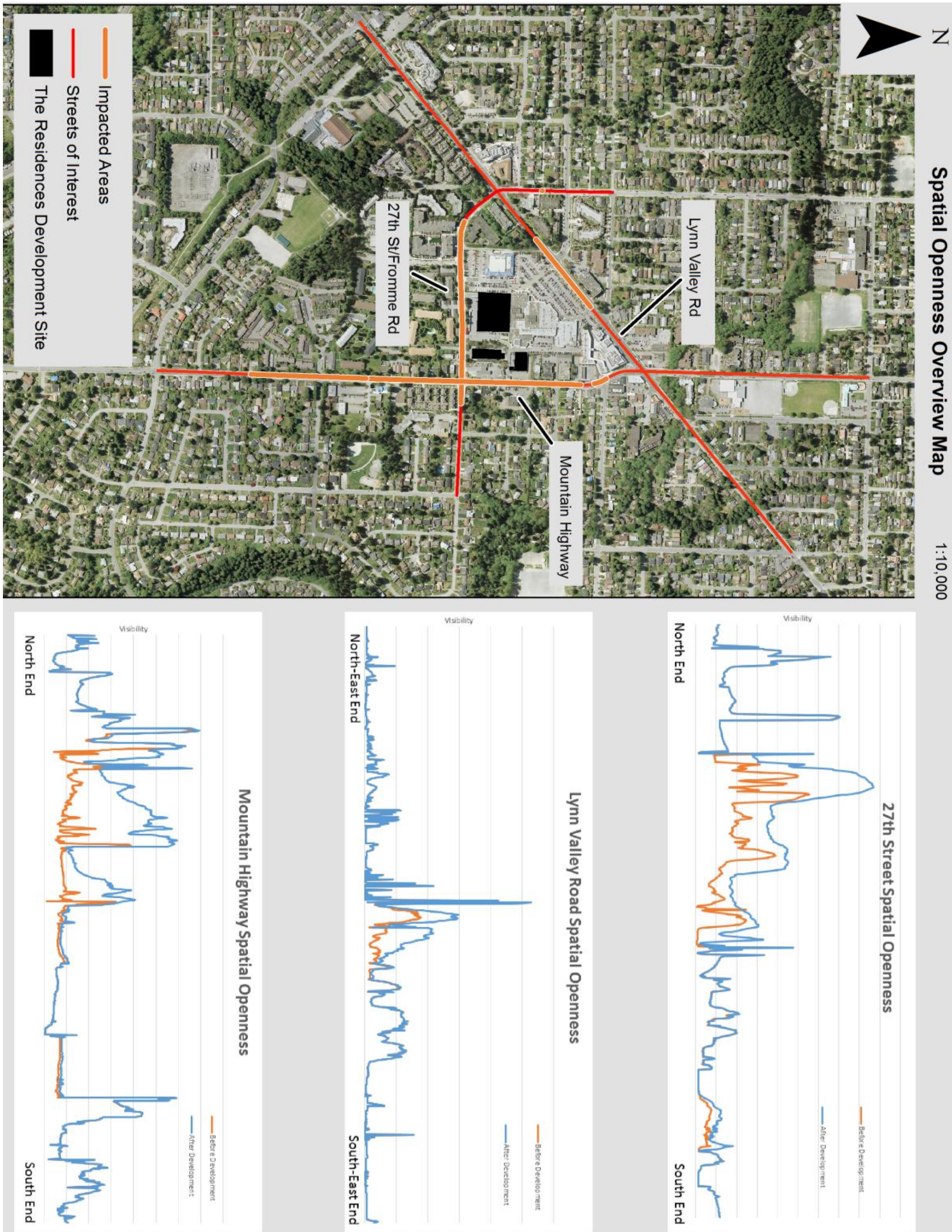
The spatial openness analysis involves creating a set of line to area isovists for three main roads surrounding the development. We calculated pre- and post-development isovists for sections of Lynn Valley Road, Mountain Highway, and 27th street (see map) to determine The Residences' impact on the surrounding area's spatial openness. For many residents, the prospect of a new development fills them with worry about the effects it will have on the community's character. Many residents of North

Vancouver feel high-rise buildings will take away from the region's intimate connection with nature. This analysis will serve to either reinforce this notion or alleviate residents' fears. To create a line-to-area isovist, we converted the road lines to points spaced 1m apart and used them as observer points for our isovist script. We used the same surface model as the visual prominence analysis because we were mostly concerned with visibility within North Vancouver. Additionally, the North Vancouver DSM is a much smaller file, which vastly reduces computation time.

Results

The spatial openness results presented in Figure 6 are surprising because they imply an increase in spatial openness after the developments have been built. These analyses allow us to quantify the feeling of openness one experiences while travelling along the roads. Many residents expressed concern that high-rises will make the community feel more claustrophobic by drastically reducing the amount of surrounding landscape one can see while driving down the street or walking along the sidewalk. Our spatial openness graphs quantify the amount of space visible along the street in one metre intervals. The results allow us to pinpoint the sections of the street set to lose or gain a sense of openness. Most importantly, the spatial openness visualizations provide stakeholders with a tangible representation of an otherwise abstract phenomenon.

Figure 12. Pre- and Post-Development Spatial Openness



3.5. Discussion

As previously discussed, the existing materials made public by the District of North Vancouver did not contain any analytical content. We do not know if any analyses were done in house and not presented, and we will not speculate about the reasons for the lack of publicly available analyses. This section will primarily discuss the impacts analyses like the ones mentioned in Section 4 may have on public dialogue and the public consultation process as a whole.

In section 4, we quantified The Residence's impact on the community's viewscape. These impacts are not often fully realized by all stakeholders until the new development has been built. At this point, it is too late for any structural changes to be made. However, if visibility analyses are performed and made public for each potential development, citizens will be able to objectively compare the impacts of multiple building designs. In urban development, stakeholders frequently wish to objectively compare two or more planning proposals (Engel and Dollner, 2009). While the DNV's existing online representations inform citizens of the size and aesthetics of new developments, they do not capture changes to viewscapes. Residential towers are very likely to have impacts on viewscapes that extend well beyond the required notification radius (75 metres). While one could argue that while property owners should not have control over space they do not own, these spaces can have an impact on their health and property values. Inadequate exposure to sunlight has been shown to adversely impact one's psychological health (Mead, 2008). Additionally, a property's market value is often partially calculated based on its viewscape (BC Assessment, 2015).

We must also discuss the limitations of our analyses. The biggest limitation is due to the manner in which "The Residences'" geometry was added to the GIS. As far as we are aware, there are no publicly available digital representations, whether they are 3D models or building footprints, of new developments. The representations used in our analyses were created by hand based on the engineering schematics produced by the developers. As such, there might be some inaccuracies in the geometry of "The Residences." However, our aim with this work is to show the types of visualizations that can be produced using industry standard GIS packages. The solution to this issue would be for municipal governments to require developers submit digital representations of new developments as part of the rezoning process. The City of Surrey, another municipality in the Metro Vancouver region, requires the submission of 3D models of new developments. As previously mentioned, another limitation is the 2.5D nature of the visibility analysis. Each geographic coordinate only has one elevation value, so overhanging structures are not properly factored into the analysis. However, our study area does not contain any bridges or buildings with large overhangs, so it should have a minor impact on the accuracy of our analyses.

Dialogue between stakeholders at public information sessions is often concerned with the potential visual impact of new developments on the existing community. However, citizens, municipal staff, and developers all have different backgrounds and levels of knowledge of the topic. Citizens adamantly argue that new developments will dominate the skyline of the community and detract from the viewscapes to which they have been accustomed. However, these concerns are often knee-jerk reactions to sudden changes in their community. Before the developments are built, there is currently no way for the average citizen to know the impacts. As we demonstrated in Section 4, it is possible to predict and visualize the potential visual impact of new developments with adequate input data. Although there is no way to validate the analysis before the buildings are constructed, they have been generated using well-tested algorithms, using geometry that closely resembles the proposed development. The visualizations we have produced can serve as the basis for productive dialogue between stakeholders.

DNV's bylaws state that residents within 75 metres of potential developments must be notified of any public hearings or information sessions. However, one would expect the visual impact of multi storey buildings to be larger than the 75 metre notification rule in DNV's bylaws. The District's existing bylaws regarding notification areas were likely written before GIS had the capability to analyze the visual impact of proposed buildings. We believe redevelopment notification zones should be flexible, as opposed to DNV's current 75 metre rule. If industry standard visibility algorithms using high resolution geographic data predict visual impacts beyond 75 metres, the notification zone should expand to accommodate those residents.

3.6. Conclusion

Publicly available geovisualizations for urban development in North Vancouver are a combination of maps and architectural renderings that do little to assess and present potential visual impacts of new developments. The maps show the locations of future developments, while the architectural renderings show carefully curated snapshots of the buildings' aesthetics. However, the existing visualizations do not take the new development's visual impact on the surrounding neighbourhood into account. In the case of The Residences, the lack of publicly available geovisual analysis resulted in widespread, unsubstantiated concerns among residents that the development would drastically alter the region's visualscape. However, our analyses have essentially disproved this notion. We believe that if the developers and municipal government had made similar analyses public early in the design process, public dialogue around its visual impact may have been more focused.

We believe the GIS analyses outlined in this paper can fill the representational gap left by existing materials provided to citizens both online and in public hearings/information sessions. Once refined, they can be used to both inform notification requirements and to provide stakeholders with a common frame of reference on which to base productive discussion during public hearings. These visualizations are only the first step in improving citizen engagement. Despite the complexity of the analyses, they are presented in a static form with no options to explore alternate perspectives. Future work in this area should involve the creation of interactive tools that allow stakeholders to view the analytical results from any desired viewpoint. Additionally, such tools should include nearly photorealistic renderings of developments to give stakeholders an accurate idea of what the buildings will look like once constructed. An interactive application that accomplishes both of these goals would be the ideal basis for productive dialogue between all stakeholders in the urban development process.

3.7. References

Andrienko, G. L., & Andrienko, N. V. (1999). Interactive maps for visual data exploration. *International Journal of Geographical Information Science, 13*(4), 355-374.

Bartie, P., Reitsma, F., Kingham, S., & Mills, S. (2010). Advancing visibility modelling algorithms for urban environments. *Computers, Environment and Urban Systems, 34*(6), 518-531.

Benedikt, M. L. (1979). To take hold of space: Isovists and isovist fields. *Environment and Planning B: Planning and Design, 6*(1), 47-65.

Buja, A., Cook, D., & Swayne, D. F. (1996). Interactive high-dimensional data visualization. *Journal of Computational and Graphical Statistics, 5*(1), 78-99.

Bunch, R. L., & Lloyd, R. E. (2006). The cognitive load of geographic information. *The Professional Geographer, 58*(2), 209-220.

Engel, J., & Döllner, J. (2009). Approaches towards visual 3d analysis for digital landscapes and its applications. *Digital Landscape Architecture Proceedings, 2009*, 33-41.

ESRI. (2016). *Viewshed.* Retrieved August 17, 2016, from http://pro.arcgis.com/en/pro-app/tool-reference/3d-analyst/viewshed.htm

ESRI. (2016). *What is ArcPy?* Retrieved August 17, 2016, from http://pro.arcgis.com/en/pro-app/arcpy/get-started/what-is-arcpy-.htm

Fisher, P. F. (1991). First experiments in viewshed uncertainty: The accuracy of the viewshed area. *Photogrammetric Engineering and Remote Sensing, 57*(10), 1321-1327.

Llobera, M. (2003). Extending GIS-based visual analysis: The concept of visualscapes. *International Journal of Geographical Information Science, 17*(1), 25-48.

Lonergan, C., & Hedley, N. (2016). Unpacking isovists: A framework for 3D spatial visibility analysis. *Cartography and Geographic Information Science, 43*(2), 87-102.

MacEachren, A. M., Edsall, R., Haug, D., Baxter, R., Otto, G., Masters, R., et al. (1999). Virtual environments for geographic visualization: Potential and challenges. Paper presented at the *Proceedings of the 1999 Workshop on New Paradigms in Information Visualization and Manipulation in Conjunction with the Eighth ACM Internation Conference on Information and Knowledge Management,* pp. 35-40.

Mead, M. N. (2008). Benefits of sunlight: A bright spot for human health. *Environmental Health Perspectives, 116*(4), A160.

Morello, E., & Ratti, C. (2009). Solar envelopes' and the analysis of urban DEMs. *Computers, Environment and Urban Systems, 33*(1), 26-34.

Morrison, T. (2014). *BC assessment explores innovative geospatial 3D modelling for property assessment.* Retrieved Feb 4http://www.directionsmag.com/pressreleases/bc-assessment-explores-innovative-geospatial-3d-modelling-for-property/378041

Statistics Canada. 2012. *Focus on Geography Series, 2011 Census*. Statistics Canada Catalogue no. 98-310-XWE2011004. Ottawa, Ontario. Analytical products, 2011 Census. Last updated October 24, 2012.

Weitkamp, G., Bregt, A., & Van Lammeren, R. (2011). Measuring visible space to assess landscape openness. *Landscape Research, 36*(2), 127-150.

Yang, P., Putra, S., & Li, W. (2007). Viewsphere: A GIS-based 3D visibility analysis for urban design evaluation. *Environment and Planning B, 34*(6), 971-992.

Chapter 4. Conclusion

4.1. Summary

The primary purpose of this thesis was to determine how GIScience and geovisualization can enhance the public consultation portion of the urban development process. Developments in spatial data acquisition, spatial analysis, and geovisualization allow us to create informative visualizations of otherwise intangible visual impacts of urban development. Informative and easily interpretable visualizations may serve to focus discussion during public meetings. This thesis comprises two discrete but related research agendas.

Chapter 2 contextualizes the use of GIS and data visualization in planning through and exploration of literature in GIScience, geovisualization, and urban planning. Next, it proposed a framework to guide the evaluation of existing geovisual public participatory planning (PPP) systems. Finally, it drew on the evaluation framework and existing visualizations to suggest the components of ideal PPP visualizations.

Chapter 3 used GIScience principles to review the District of North Vancouver's (DNV) existing publicly available representations of "The Residences at Lynn Valley," which has seen a contentious public consultation process. Following an in-depth review of existing materials, it proposed and demonstrated a series of visibility analyses that quantified the development's visual impact on the existing community. The purpose of this chapter was not to produce and validate new visibility analysis techniques. Rather, it was to use existing analytical techniques for innovative visualizations designed to help focus public dialogue.

4.2. Research Contributions

Chapter 2 explicitly linked PPP and GIS literature to provide a rationale for including GIS in the pubic participatory process. Additionally, it re-imagined the role of geovisualization in urban development using Arnstein's (1969) foundational ladder of citizen participation. Next, it provided a comprehensive review of the methods of representation, analysis, and geovisualization, as well as an evaluative framework with which to evaluate new and existing studies. The evaluative framework contains a set of characteristics that, when combined, should result in a robust and effective visualization that maximizes knowledge transfer. From our sample, we determined the most common method of representation uses 2.5D dimensionality. This means 2D data is presented in a 3D visualization. The use of 3D visualizations is ideal due to their similarities to a stakeholder's lived, sensory experience in place (MacEachren et al., 1999; Slocum, 2009). However, 3D visualizations derived from 2.5D data imply a level of sophistication in the analysis that is absent. I do not mean to imply any kind of malicious misdirection by visualization designers, as they are often limited by existing datsets, which are most often two-dimensional. However, recent developments in affordable SFM modelling show promising preliminary results in cheap, fast, and topologically 3D data gathering. I expect to see wide adoption of SFM data collection in the coming years.

Additionally, our evaluations provided us with a sense of trends in data representation characteristics, such as dynamism in visualizations, dynamic re-expression, and real time rendering. The most common representational characteristic was real time rendering, which is a core function of any 2D or 3D data viewer. Less common representational characteristics like dynamic re-expression and multi-resolution rendering were far less common. These features require time and expertise in 3D modeling lacking in most academics. The most common interactivity feature is the ability for the user to change their viewpoint, while others such as brushing, highlighting, and multiple linked views less common. In a similar vein to the representational features, the commonality of interactivity features depends on the built-in capabilities of existing software. Public consultation for urban development is most often accomplished with shoestring budgets, which are unlikely to allow for the development and testing of experimental features.

Chapter 3 provides an overview of the methods of representation, analysis, and geovisualization as manifest in the District of North Vancouver's urban development proposal dialogue. It delivers an analysis of current public consultation practices in the DNV based on the theoretical perspective established in Chapter 2. My study revealed the dominant methods of representation (as discussed in Chapter 2) were a mixture of 2D maps and 3D perspective architectural renderings. The existing materials available to the public do not show evidence of GIS visibility analyses, which led to widespread concern about The Residences' visual impact on the surrounding community. The lack of publicly available analysis is a major limitation. Due to a lack of information, the aspects of public dialogue concerning The Residences' visual impact were unfocused, unproductive, and took time away from broader issues like the development's potential impacts on traffic. Our GIS analyses are based on a review of isovist and visibility analysis from the relevant literature in the context of structural changes in urban development. They consisted of a parcel-by-parcel visual impact analysiswe, street-level spatial openness analyses, and a development-centric visual prominence analysis. The analyses should serve as a starting point for the continued development of a geovisual and analytical framework to accurately and objectively provide citizens with an idea of the impact of new developments. The analyses determined The Residences' visual impact was less severe and widespread than many citizens feared. Moreover, they could provide a common frame of reference for productive dialogue between all stakeholder groups.

4.3. Discussion

4.3.1. Limitations and Implications of Current Practice

The limitations of visualizations used in public consultation for urban development stem from the methods of representation, analysis, and visualization, and the nature of public forums themselves. Public forums often take place in the evening in a location that is not always accessible to the injured, people with disabilities, or those without reliable transportation. Furthermore, due to individuals' varying time constraints, it is not always possible for information to be shared in person. Also, public hearings cater to vocal citizens with extreme views that do not align with the general public (Kinston et al., 2000). Discussion at public forums is carried out through a speakers list, which often results in a series of brief speeches from citizens. These speeches are, at best, tenuously connected with little opportunity for productive discussion. If a citizen wants to voice their opinion, they have to apply to the clerk to Municipal Council, must be willing to state their name and address on camera and give a tightly-timed (three-minute) speech to municipal council. Those uncomfortable with public speaking are limited in their ability to voice their concerns. Comfort with public speaking should not be required to voice one's opinion.

For public hearings to be productive, it is necessary to ensure all stakeholders are privy to the same information. Current methods for disseminating information pertinent to the impacts of urban development make it difficult for the average citizen to stay informed. Each major stakeholder group approaches urban development with different levels of knowledge; and different capabilities to inform other stakeholders. Technology can be used to minimize information asymmetries between citizens, municipalities, and developers, but the methods employed by DNV do not reach the technology's full potential. Regardless of the venue, information about future developments is presented using engineering drawings, maps, annotated aerial photos, and architectural renderings. These media are not adequate for people who are not design oriented (Al-Kodmany, 1999). Additionally, architectural renderings are shown to citizens as snapshots from pre-selected perspectives. While this is a step in the right direction, it falls short of the interactivity levels necessary for users to explore a depiction of new developments. Interactive, 3D depictions of new developments are likely to take advantage of the same human cognitive and sensory systems used in the real world, which increases the potential for knowledge transfer (MacEachren et al., 1999; Dykes et al., 2005; Slocum et al., 2001). There are no public examples in DNV of spatial analyses that attempt to predict the impact of new developments.

The current status quo of information exchange has several social equity implications. The limited scope of the information presented to the public endangers the democratic nature of the public consultation process because all stakeholders are not privy to the same information. Information asymmetries exacerbate imbalances of power within and between stakeholder groups. While municipal council members and developers have the information necessary to take part in dialogue, only citizens with adequate time and expertise can be adequately informed of new developments. Those without adequate expertise rely on those with more information to explain the situation. They have no way to tell if they are being presented an unbiased view. There is no guarantee that maps and visualizations derived from 3D data and analysis will be unbiased. However, bias is less likely if the data are not distorted and visualization designers use standard algorithms for their analyses.

4.3.2. The flow of information for public sense-making

The use of technology in public consultation for urban development, critically, mediates information transfer, and influences the morphology of power relations in the process. Under the status quo, even if all materials are public, the average citizen does not have enough time nor expertise to familiarize themselves with development proposals (Day, 1997). This relative lack of familiarity with proposals compared to planners and developers cultivates an image in which citizens are not qualified to make meaningful contributions (Kweit and Kweit, 1999). Careful use of geographic data, analysis, and visualization is the first step to bridging the knowledge gap between stakeholders. Perspective 3D visualizations allow a wide array of information to be presented in a way that allows viewers to instantly connect the representation with their lived experience. It is impossible for developers of digital maps and visualizations to have complete control over what happens when those outputs are released to the public. Maps, and visualizations more generally, are viewed, interpreted, adopted, and used in many ways beyond their originally intended purpose, which highlights the need for objectivity. Those responsible for creating visualizations need to ensure their work reflects the multiplicity of lived experiences in a place. Visualizations can be used to persuasively convey the importance of ideas more efficiently than text alone (Wood and Fels, 1992). With that said, designers need to be careful to avoid ‘sanitized’ representations that hide the grittiness of reality.

If citizens have the necessary tools to approach the public consultation process with a better understanding of relevant development proposals, they are more likely to substantively contribute to dialogue between stakeholders. Existing practices resemble consultation from Arnstein’s (1969) ladder of citizen participation. A better-informed citizenry is more likely to elevate to the higher rings of the ladder, such as partnership. Ideally, participation should be a dynamic process that gives all stakeholders a sense of ownership and involvement in the process (McTague and Jakubowski, 2013). The responsibility to foster a well-informed citizenry falls on developers and municipal staff because the average citizen does not have the resources or expertise to conduct spatial analyses on their own.

4.3.3. Recommendations to improve current policy/practice

GIS and visualization technologies can provide citizens with a method to see how proposed urban developments will change their physical environment. It is a worthwhile venture for municipal governments to explore how emerging methods of spatial analysis and visualization might inform their public consultation process. Animated and 3D views are considered by many to be particularly effective at communicating the implications of future scenarios (Al-Kodmany, 2000). Visualizing the results of spatial analyses reveals information about potential developments that is otherwise impossible to examine until they are built. GIS is a powerful visualization tool that can be used to proactively prevent misunderstandings when public agencies make changes at the neighbourhood level (Al-Kodmany, 2000). However, increasingly complex 3D analyses need equally detailed 3D datasets to produce reliable results.

To produce valid 3D spatial analytical visualizations, the GIS requires high resolution datasets that represent the landscape before and after development. LiDAR data is a valid, albeit expensive, option for pre-development data. If LiDAR is not an option, structure from motion (SFM) modelling allows for the generation of complex 3D data using a series of photos. Next, the GIS needs an accurate representation of the new development's geometry. To this end, developers should be required to submit 3D models of their proposed development to the municipality as part of their rezoning proposal. While this option sounds good in theory, it is not without complications. The largest barrier to entry is the extra computational power and capacity needed to analyze and store detailed 3D data.

Visualization creation is only a part of what is necessary to ensure citizens' access to information. Information distribution is an equally pressing concern. Although this document only briefly discusses Web GIS, I believe municipalities should consider using it to disseminate information. If it is utilized to its full potential, it gives citizens access to the information presented at public hearings while allowing people to present their opinions without the confrontational overtones of most public hearings (Innes and Booher, 2005). However, some academics have scorned GIS as another instrument of capital control and government surveillance (Pickles, 1995; Curry, 1998; Aitken, 2002; Sieber, 2006). This idea is both technologically deterministic and reductionist because it ignores aspects of technology, such as practices, laws, organizational arrangements, and the required knowledge for its use (Innes and Simpson, 1993). Despite GIS's institutional origins, PPGIS has been predominantly led by grassroots groups and community based organizations that use it as a tool for capacity building and social change (Sieber, 2006). GIS technology operates within, and its use is a product of, the social environment in which it is used.

Without a human component, even the most sophisticated technology will not produce meaningful inputs. Participatory mapping should be used iteratively in the public participation process, instead of producing a single product (Bailey and Grosshardt, 2010; Brown and Kytta, 2014). If used responsibly and objectively, GIS can provide all stakeholders with an objective and consistent frame of reference for productive dialogue that links expert knowledge with citizens' insight. Pairing expert knowledge with citizen insight is one of the primary goals of PPP. Most importantly, municipal governments and developers need to be willing and able to listen to and implement citizens' feedback. If they are not willing to do so, the whole process is tokenism at best.

4.4. Future Directions

The research contained in this thesis presents a wide variety of potential future work. The urban development visualization evaluations in Chapter 2 only focused on the visualizations themselves, as opposed to how they were used in the public consultation process as a whole. The framework could be adapted and expanded to provide a more holistic evaluation of the entire public consultation process. This would require a variety of interviews with planners, developers, municipal employees, and citizens to determine if the visualization systems helped or hindered the process. Furthermore, as mentioned in the chapter, the evaluations were based only on images and text descriptions from the authors of each study. For the most part, the visualization systems were not designed as online tools, which made closer inspection impossible. Additionally, the links provided by studies using online tools were no longer working. In order to properly assess the effectiveness of PPP visualization systems, we would require access to the system itself. Moreover, a comprehensive usability study would require a range of human subjects with a wide degree of competencies for technology. There is also a wide range of user input and eye tracking tools available to glean deeper insight into how users are actually using a visualization system.

While Chapter 3 provides a range of rarely-seen visualizations that succeed in making tangible the intangible effects of urban development, there are still areas for further development. Although the input data was 3D, our analysis was 2.5D and the visualizations were 2D. I elected to stay with 2.5D analysis for this study in order to maintain the size of our study area with the available computing power. Future work would include the implementation of topologically 3D visibility analysis, which would require more computing power and storage. Additionally, the analytical results are presented using static 2D maps. In some cases, this is an ideal method to present information to the end user. This is likely the case for the viewscape impact analysis for each property parcel surrounding "The Residences." However, the visual prominence visualizations would be more effective in an interactive 3D environment where users can, at the very least, pan and zoom around the model results. While this chapter's analytical visualizations reveal many of "The Residences'" currently intangible visual impacts, they do give the audience a sense of what the new developments will look like from a human standpoint. Future work in this area should involve both the creation of a both virtual reality (VR) and augmented reality (AR) applications that aim to give users a tangible representation of what future developments will look like *in situ*.

In closing, this thesis is part of a broader research agenda that seeks to find new and innovative ways of using the principles of GIScience and geovisualization in combination with emerging mapping methods and technologies to enhance public participation in urban development. It is imperative that any future work in this area is done in conjunction with urban development stakeholders. The sophistication of the analyses and interface are meaningless if they are never used.

4.5. References

Aitken, S. (2002). Public participation, technological discourses and the scale of GIS. *Community Participation and Geographic Information Systems,* , 357-366.

Al-Kodmany, K. (1999). Using visualization techniques for enhancing public participation in planning and design: Process, implementation, and evaluation. *Landscape and Urban Planning, 45*(1), 37-45.

Al-Kodmany, K. (2000). GIS in the urban landscape: Reconfiguring neighbourhood planning and design processes. *Landscape Research, 25*(1), 5-28.

Arnstein, S. R. (1969). A ladder of citizen participation. *Journal of the American Institute of Planners, 35*(4), 216-224.

Bailey, K., & Grossardt, T. (2010). Toward structured public involvement: Justice, geography and collaborative geospatial/geovisual decision support systems. *Annals of the Association of American Geographers, 100*(1), 57-86.

Brown, G., & Kyttä, M. (2014). Key issues and research priorities for public participation GIS (PPGIS): A synthesis based on empirical research. *Applied Geography, 46*, 122-136.

Curry, M. (1998). *Digital places: Living with geographic information technologies* Routledge.

Day, D. (1997). Citizen participation in the planning process: An essentially contested concept? *Journal of Planning Literature, 11*(3), 421-434.

Dykes, J., MacEachren, A., & Kraak, M. -. (2005). Exploring geovisualization. In J. Dykes, A. M. MacEachren & M. -. Kraak (Eds.), *Exploring geovisualization* (1st ed., pp. 1-19) Pergamon.

Innes, J. E., & Booher, D. E. (2004). Reframing public participation: Strategies for the 21st century. *Planning Theory & Practice, 5*(4), 419-436.

Kingston, R., Carver, S., Evans, A., & Turton, I. (2000). Web-based public participation geographical information systems: An aid to local environmental decision-making. *Computers, Environment and Urban Systems, 24*(2), 109-125.

Kweit, R. W., & Kweit, M. G. (1999). *People & politics in urban america* Routledge.

MacEachren, A. M., Edsall, R., Haug, D., Baxter, R., Otto, G., Masters, R., et al. (1999). Virtual environments for geographic visualization: Potential and challenges. Paper presented at the *Proceedings of the 1999 Workshop on New Paradigms in Information Visualization and Manipulation in Conjunction with the Eighth ACM Internation Conference on Information and Knowledge Management,* pp. 35-40.

McTague, C., & Jakubowski, S. (2013). Marching to the beat of a silent drum: Wasted consensus-building and failed neighborhood participatory planning. *Applied Geography, 44*, 182-191.

Pickles, J. (1995). *Ground truth: The social implications of geographic information systems* Guilford Press.

Sieber, R. (2006). Public participation geographic information systems: A literature review and framework. *Annals of the Association of American Geographers, 96*(3), 491-507.

Slocum, T. A., Blok, C., Jiang, B., Koussoulakou, A., Montello, D. R., Fuhrmann, S., et al. (2001). Cognitive and usability issues in geovisualization. *Cartography and Geographic Information Science, 28*(1), 61-75.

Slocum, T. A., McMaster, R. B., Kessler, F. C., & Howard, H. H. (2009). Virtual environments. *Thematic cartography and visualization* (3rd ed., pp. 460-477). Upper Saddle River, NJ: Pearson Prentice Hall.

Wood, D., & Fels, J. (1992). *The power of maps* Guilford Press.