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Article

Tool or Toy? Virtual Globes in Landscape Planning

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Abstract: Virtual globes, *i.e.*, geobrowsers that integrate multi-scale and temporal data from various sources and are based on a globe metaphor, have developed into serious tools that practitioners and various stakeholders in landscape and community planning have started using. Although these tools originate from Geographic Information Systems (GIS), they have become a different, potentially interactive and public tool set, with their own specific limitations and new opportunities. Expectations regarding their utility as planning and community engagement tools are high, but are tempered by both technical limitations and ethical issues [1,2]. Two grassroots campaigns and a collaborative visioning process, the Kimberley Climate Adaptation Project case study (British Columbia), illustrate and broaden our understanding of the potential benefits and limitations associated with the use of virtual globes in participatory planning initiatives. Based on observations, questionnaires and in-depth interviews with stakeholders and community members using an interactive 3D model of regional climate change vulnerabilities, potential impacts, and possible adaptation and mitigation scenarios in Kimberley, the benefits and limitations of virtual globes as a tool for participatory landscape planning are discussed. The findings suggest that virtual globes can facilitate access to geospatial information, raise awareness, and provide a more representative virtual landscape than static visualizations. However, landscape is not equally representative at all scales, and not all types of users seem to benefit equally from the tool. The risks of misinterpretation can be managed by integrating the application and interpretation of virtual globes into face-to-face planning processes.

Keywords: virtual globes; landscape visualization; open data; Geographic Information Systems; landscape planning; community engagement; scenario planning

1. Introduction

In 1998, Al Gore presented the vision of a "Digital Earth" embedding geo-referenced data in a multi-resolution, three-dimensional representation of the Earth, facilitating collaboration to understand the interaction between human impacts and the environment [3]. With the rapid development of both commercial and scientific 3D geobrowsers representing the earth, technological development has approached, although not reached, Al Gore's vision. Virtual globes can be defined as geobrowsers, based on a globe metaphor, that integrate multi-scale and multi-temporal data from various sources. They have become a popular tool, and expectations regarding their utility as planning and community engagement tools are high, but are tempered by both technical limitations and ethical issues [1,2,4].

In a position paper for the Vespucci Initiative for the Advancement of Geographic Information Science, Craglia *et al*. [3] set up a research agenda on the use of virtual globes. In addition to research in areas such as information integration and governance models, they called for case studies incorporating up-to-date modeling and indicators that would visualize abstract concepts in space such as "quality of life" or "vulnerability". Personal anecdotal evidence from discussions with representatives of community groups and local government also points to the need for collaborative frameworks employing easily accessible tools to visualize, explore and assess development alternatives, as well as local climate change vulnerability, impacts, and response options, within their spatial context [5].

This paper responds to Craglia *et al*.'s [3] call for case studies, and builds on Sheppard and Cizek's [1] previous discussion of virtual globes, particularly related to the potential benefits of virtual globes in providing access to visual information, stimulating citizen interest, and providing representative views. Using two bottom up participant-driven introductory examples, and the Kimberley Climate Adaptation Project (KCAP) as a case study, the paper examines how far potential benefits can be fulfilled in practice. The paper demonstrates how, when used in tandem with other media, virtual globes can: (i) provide access and a shared platform for diverse spatial inputs from multiple stakeholders; (ii) raise interest and awareness of complex spatial environmental data and modeling outputs; and (iii) help to present locally relevant issues, vulnerabilities and possible response actions. However, several issues have been observed with their use that limit virtual globes' effectiveness in planning processes, including: (i) issues of visual representativeness at global, regional and object scales; (ii) affective responses; and (iii) the risk of misinterpretation. These are examined in greater detail in the Kimberley case study in Section 4. The paper concludes with observations about how to address the identified limitations and risks, and how and when such tools might best be employed in collaborative planning settings.

2. Theoretical Framework for Assessing Virtual Globes

The original vision of a virtual globe was rather utopian, seeing it primarily as an enabling tool that would make previously inaccessible geodata accessible to the general public, thereby helping to achieve environmental and social goals such as preserving biodiversity and modeling climate change. However, while the development of virtual globe software platforms has vastly increased access and exposure to some spatial information, and interactive tools and platforms have been provided for user-generated content, major constraints persist. Much data and parts of the software continue to remain in the hands of large companies and government. Thus, some authors have formulated alternative dystopian views of virtual globes as tools for "disaster capitalism" that distract from, rather than empower, necessary action on the ground [6]. In contrast to both utopian and dystopian views of virtual globes, Kingsbury and Jones [7] come to the conclusion that technology can be applied in a variety of contexts and uses, potentially with opposing outcomes. This paper begins from this third way of assessing technology, where the technology is seen as socially constructed and its use as socially mediated and contested. It can therefore be applied in different contexts, but is not in itself either utopian or dystopian. A brief overview of the genesis and current state of virtual globes, their role and use as an agent for social change, possible benefits, and previously identified limitations and risks provide the context and an assessment framework for the examples in Section 3 and the case study research in Section 4.

2.1. Development of Virtual Globes to Date

Compared to Geographic Information Systems (GIS), virtual globes only have basic GIS analytical functions such as measuring and identifying attributes [2]. Unlike popular 2D online mapping tools such as Google Maps, Bing Maps, and Open Street Map, virtual globes provide oblique views of detailed aerial photos and multiple uses of visual signs as overlays on top of the pictorial imagery, combined with 3D objects. Virtual globes include the open source NASA WorldWind, scientific prototypes under development in China and Australia, the commercial (although partly free to use) products Microsoft Bing Maps 3D, ESRI ArcGIS Explorer and ArcGlobe, Google Earth [8], and the open source Biosphere3D, which is designed specifically for landscape visualization (http://www.biosphere3d.org). According to Tuttle *et al*. [9], virtual globes are particularly successful for uses in education, scientific research and collaboration, and disaster response.

Google also provides free tools such as Sketchup to generate 3D content for virtual globes. Over the last few months, Google has launched additional geospatial tools, particularly the new Google Earth version 6, which supports 3D tree models [10], Google Earth Builder, an online GIS for geodata management, Google Earth Engine, a future environmental monitoring platform that adds more complex analytical functions, and the Open Data Kit, a set of tools for mobile data collection.

2.2. Virtual Globes as Participatory Landscape Visualization Platforms: Benefits and Limitations

The following discussion summarizes various criteria and evaluative approaches to virtual globes. The authors draw on prior work on mostly theorized (and sometimes realized) benefits and risks from the fields of Public Participation Geographic Information Systems (PPGIS) and landscape visualization.

In terms of public engagement, the considerable overlap between virtual globes and the field of PPGIS can provide valuable insight into how best to make use of virtual globes. Dodge and Perkins [11] raise questions related to "tensions between confidentiality and freedom of information; the changing status of visual technologies; the relations between power, space and representation; everyday and elite practice; and forms of resistance". In this context, Sieber [12] classifies two different types of PPGIS initiatives: top down and bottom up. Top down approaches include any government activities, such as mapping community assets and deficits, to support top-down defined goals. In contrast, grassroots initiatives use PPGIS, and increasingly virtual globes, to map and visualize citizen-defined issues. This paper does not evaluate pure top-down approaches, which tend to lack substantive participation; instead, the KCAP case study will present a collaborative approach to decision-making, which includes government and external experts, but is led by local stakeholders and citizens.

There have been high expectations about the deliberative power of virtual globes as an accessible type of geobrowser, arguably providing grassroots groups with equal means to corporations or developers or governments [13]. Phadke [14] challenges the potential of virtual globes to facilitate grassroots action and initiate policy shifts. While agreeing that the tool can raise awareness about activities with high landscape impacts, such as mining activities, Phadke is concerned that virtual globes add only limited value to the representation of future landscapes because virtual globes don't cover the complex symbolic meanings of landscapes. Phadke's argument is only theoretically, rather than empirically, supported and Phadke notes that more research is required on public response and the possible "strategic costs", e.g., the lack of public trust in employing virtual globes as a tool in grassroots campaigns. Focusing on participatory potentials of virtual globes, the following chapter will look at two-bottom up grassroots examples in more detail. The main part, the KCAP case study, will present a collaborative approach to decision-making, which includes government and external expert but is led by local stakeholders; attempting to combine the power of bottom up participation with the resources of public planning.

Virtual globes provide a high apparent pictorial realism in the elevated oblique views due to their use of high resolution satellite and aerial images—a perspective that has often been used in landscape related disciplines. For example, Dodge and Perkins [11] argue that virtual globes can be related to landscape painting because they provide a similar "framing" of extensive geographic spaces [15]. Thus, the field of landscape visualization can provide guidance on the requirements of stakeholders regarding feasibility, flexibility, and engagement [16], and how to produce and assess interactive representations of the landscape [17] in virtual globes.

Lange [18] sees easier access to geospatial information (Benefit 1 in Table 1) as one of the major benefits of virtual globes. Lange [19] also found that approximately 75% of test participants assessed virtual landscapes as highly realistic. Most of those landscapes were similar to the background scenes that virtual globes are most known for: a detailed orthophoto combined with 3D objects. In contrast, middleground and foreground scenes received lower, albeit still medium to high, realism level ratings. When "zoomed in", virtual globes allow the viewers to position themselves in an immersive eye-level view on the ground, but in most cases, the realism appears to be lower than it is in the elevated oblique "landscape" view. Consequently, Google covers the foreground scenes with its complementary service StreetView for select built-up areas. It is still an open question how much cognitive load these diverse landscape impressions impose on the user and how different user groups can cope with that cognitive load [20,21].

Sheppard [22] earlier defined accuracy, representativeness, visual clarity, interest, legitimacy, access to visual information, framing, and presentation as crucial criteria for the ethical use of landscape visualizations in general. Sheppard and Cizek [1] published the first critical discussion of virtual globes for landscape related disciplines. They focused on key issues such as landscape perception that moves beyond cartography to cross a crucial threshold into experiential imagery. Such imagery can evoke more emotional and value-laden, potentially overwhelming, cognitive responses [23]. Additional 4D (time-collapsing) and animation features can increase public interest and awareness but may also add too much drama and cognitive load [17,24]. If virtual globes are used online without face-to-face explanation or detailed written background information about underlying data and methodology, the risk of misinterpretation or bias is likely to increase [11].

Issues related to projecting future conditions are particularly relevant for this project: the field is largely technology-driven and therefore more focused on the evaluation of technical performance and realistic rendering rather than validity and reliability in a scientific sense. Sheppard and Cizek [1] identify further potential risks when experts and lay people use virtual globes in planning. Issues around data and software, perceptual issues, and power implications of data ownership, expert knowledge and corporate user terms can create unsolved ethical issues if virtual globes are applied in political processes. Goodchild [25] notes that the horizontal positional accuracy of images can be as low as +/− 60m. Despite the participatory benefits of user-generated content or Volunteered Geographic Information (VGI), the accuracy problem is aggravated through the incorporation of VGI because VGI come in a variety of scales with different levels of certainty and detail, often without documentation or metadata. Furthermore, most virtual globes lack features to document metadata or make data quality transparent to the user. If the representation appears to be more realistic than the accuracy of the underlying data allows, the resultant "apparent realism" can be misleading.

In a multiple case study in China, Shupeng and van Genderen [26] document the diverse datasets from multiple disciplines that were integrated in a virtual globe, increasing the accessibility of diverse datasets across multiple disciplines. Sheppard and Cizek [1] also identify potential benefits of using virtual globes in landscape planning, including increased accessibility of geospatial information, the potential for increased interest and awareness, and in contrast to static landscape visualizations, a higher representativeness of the landscape because users can choose multiple individual viewpoints (Table 1).

Table 1. Key benefits of using virtual globes to provide landscape visualizations (Sheppard and Cizek 2009: 6).

1. Access to visual information	Open free access for all Internet users with high-speed connections and reasonably up-to-date computers, providing relatively equitable access to information within the "developed" world (especially across remote areas or scattered users), though probably concentrated more on those who are younger, more affluent, with more formal education, and higher levels of computer literacy [27,28].

Table 1. *Cont.*

2. Interest	More meaningful and enjoyable engagement in viewing or manipulating information, plus increased interest with viewing familiar locations. This is consistent with increased engagement observed with other kinds of landscape visualization [29,30].
3. Representativeness	Freedom to view places or features from any angle of height, and from any number of views instead of the more conventional limited selection of static views determined by the creator of the visualizations. This is consistent with theorized benefits for representativeness in interactive landscape visualizations [22,31].

Table 1 was based on the available research at that time and few new case studies have been conducted on the benefits of virtual globes with regard to landscape related issues. This study continues the research by focusing on the potential benefits from Sheppard and Cizek [1], asking: How far are these potentials achieved in practice?

3. Bottom up Meets Top down–The Emerging Use of Google Earth by Grass Root Initiatives

The following two examples describe landscape related virtual globe applications in grassroots campaigns for Texada Island, BC, and for the City of Vancouver and its protected views of the North Shore mountains. The examples were conducted by two of the co-authors as part of advocacy grassroots campaigns and represent a first attempt to investigate the often promoted participatory potential of virtual globes in real world contexts [13]. They are considered illustrative of project and policy-specific applications of virtual globes in grassroots movements in the sense of Sieber [12] and Phadke [14]. Assuming that the context determines the role and impact of virtual globes [7], it is necessary to discuss the political context and the policy outcomes of the use of the tools. While the grass-roots visualizations seem to resonate with viewers, further assessment is needed to understand the measurable impacts of visualizations within planning processes.

3.1. Bottom-up Example: Quarry and Barge Loading Facility on Texada Island

3.1.1. Background

In May 2009, Lehigh Northwest Cement applied to the provincial government to build a quarry and barge loading facility in Davie Bay, Texada Island, British Columbia, with plans to extract 240,000 tonnes of limestone per year. This is 10,000 tonnes less than the 250,000 tonnes per year that trigger an environmental assessment under British Columbia legislation [32].

Texada Island has a long history of hard-rock mining and quarrying dating back over one century [33]. With traditional mining and logging jobs in decline, the community was split regarding the project [34]. A local citizens' group "Friends of Davie Bay" was formed to "defend Davie Bay and lobby the BC and Federal governments to refuse the Lehigh application and preserve the valuable Crown lands and foreshore for public use" [32].

3.1.2. Methods

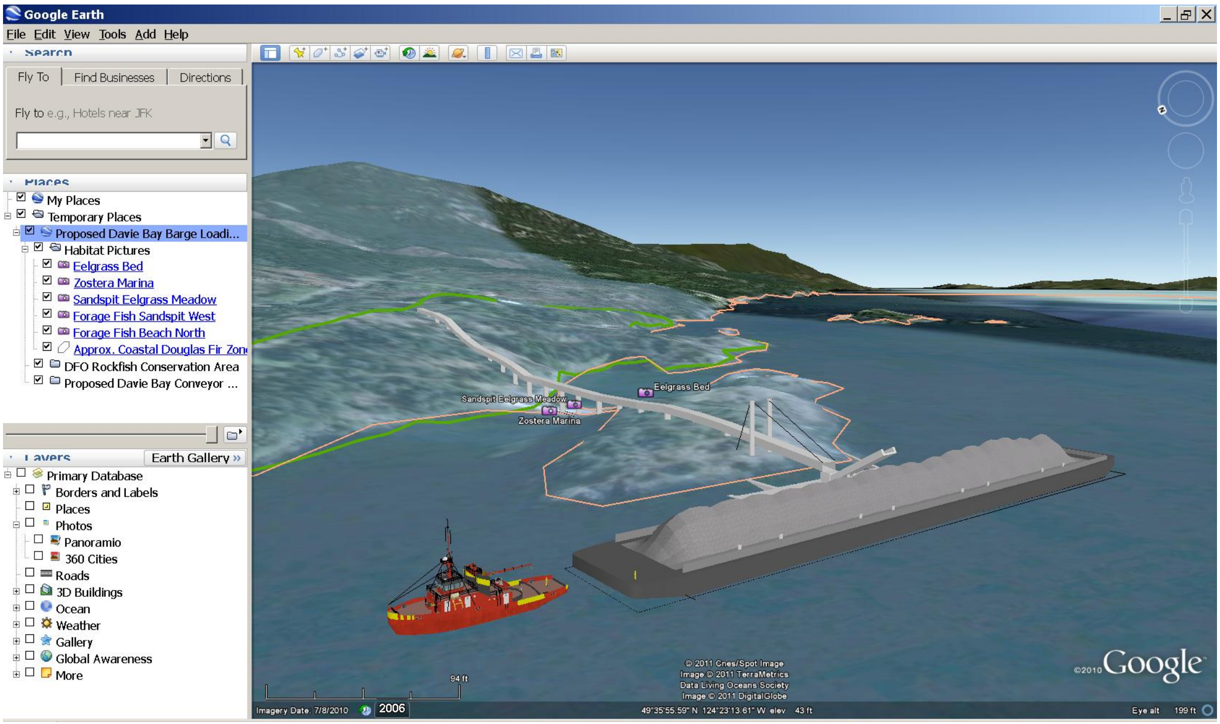
Friends of Davie Bay used a multi-media approach in their submissions requesting a full environmental assessment to the provincial and federal government, including letters, scientific reports, PowerPoint presentations, photographs, and movies. Friends of Davie Bay also commissioned a Google Earth landscape visualization of the proposed barge loading facility, which was combined with overlapping and nearby sensitive ecological features. Lehigh's application included plan and sectional engineering drawings prepared in AutoCAD format. Friends of Davie Bay requested these digital data, but Lehigh declined to make them available. Based on the author's experience with resource extraction projects, the lack of publicly available industry (and sometimes government) geo-data is quite common in grass-roots advocacy contexts [35]. Therefore, Lehigh's hard-copy drawings were scanned on a large-format scanner and then geo-referenced in ArcGIS, a common workaround to ensure the accuracy and credibility of resulting geo-data. The 3D conveyor belt was drawn in Google SketchUp software while the tugboat, barge, and figures of workers were downloaded from the SketchUp 3D Warehouse [36].

Overlapping and nearby sensitive ecological features included polygon data ("Coastal Douglas Fir Zone" and the "Rockfish Conservation Area") and point data ("Eelgrass Bed", "Sandspit Eelgrass Meadow", "Forage Fish Sandspit West and North"). Using Google Earth, the polygon data were digitized from maps in government reports [37,38]. The point data also included hyper-link "balloons" to photographs by Friends of Davie Bay. All features used pre-defined "snapshot views" so that Google Earth would automatically move to defined viewpoints when specific features were clicked.

3.1.3. Results

Friends of Davie Bay used the Google Earth landscape visualization in their presentation to a meeting of federal regulators in an environmental screening coordinated by Transport Canada on February 10, 2010. The presenter used a laptop computer connected to an LCD projector to show the barge loading facility and the overlapping sensitive ecological features from a variety of viewpoints. According to the presenter, government regulators acknowledged the Google Earth visualization as "especially powerful" because they were able to see, from multiple viewpoints, how the proposed barge loading facility would intersect the various sensitive ecological features (see Figure 1) [39]. Nevertheless, both federal and provincial regulators decided that a full environmental assessment of the project was not required. Friends of Davie Bay challenged this decision in court but lost [40].

Figure 1. Quarry and Barge Loading Facility on Texada Island (Cizek 2010; © Google 2010, © 2010 Cnes/Spot Image, Image © Terra Metrics, Data Living Ocean Society, Image © DigitalGlobe).



3.1.4. Discussion

The Texada Island example illustrates the application of "Interoperability and Mashups", where Google Earth allows layers with disparate themes and from multiple sources to be easily integrated and visually overlaid showing functional relationships [2]. It also illustrates the benefit of "representativeness" where virtual globes allow "freedom to view places from any angle or height and from any number of views [...] instead of the more conventional limited selection of static views determined by the creator of the visualizations" [1]. While formal user-response research to the visualization was not part of this example, anecdotal evidence indicates that government regulators had a strong affective (emotional) response to the visualization, expressed as surprise upon seeing the proximity of the proposed barge loading facility to the sensitive ecological features [39]. While this could be hypothesized as an example of "cognitive dissonance" in public decision-making [41], the lack of a formal evaluation precludes such suppositions. The Texada Island example thus points to a need for further research on actual decision-making outcomes resulting from the application of landscape visualization in virtual globes. Such research would ideally be inter-disciplinary as it crosses the boundaries of geospatial, social and political sciences.

3.2. Bottom-up Example: Vancouver Views

3.2.1. Background

In 2008, Vancouver City Council commissioned the "Vancouver Views: Downtown Capacity and View Corridors Study" to review the city's view corridors and identify possible changes to achieve additional development capacity through higher downtown buildings outside protected view corridors [42]. The report made multiple recommendations to amend the View Protection Guidelines and revise the General Policy for Higher Buildings. The report contained 2D maps and 3D computer visualizations, produced by city staff in 3D Studio Max, showing the visual impact of increasing the potential buildings heights of parts of the Central Business District (CBD) to 600 feet, with a single site suggested at 700 feet, heights in the shoulder areas adjoining CBD were recommended from 400 to 550 feet, while allowing a single high-rise building at the edge of the Burrard Bridge Gateway [43]. The report and its implications were consequently challenged by the West End Neighbours (WEN), a non-profit society (http://www.westendneighbours.ca/), in public meetings, open letters, and a public campaign. In particular, WEN questioned the selection of view corridors that determine the new maximum heights for future development.

3.2.2. Methods

One of the papers' co-authors with a degree in landscape architecture and experience in computer graphics programming volunteered to produce alternative 3D landscape visualizations based on the City's reports, and the City's Open Data (e.g., property lines, terrain data, and orthophotos, but no buildings). The massing models of the future high-rise buildings were exported from SketchUp according to the heights in the City's report [43] and the volunteer programmed an application to calculate view cones according to the City's view cone specifications [44]. Final visualization took place in Google Earth, using Google Earth's textured buildings for Vancouver. Photos were used to compare the visualizations with viewpoints around the city, including one viewpoint at Spanish Banks.

3.2.3. Results

Figure 2 and other static 3D visualizations exported from Google Earth were used by the co-author and by WEN representatives in PowerPoint presentations in public meetings, council meetings, in WEN letters to newspapers, and published on YouTube and the WEN website. Local media picked up the story and an account of the media coverage suggests that the visualizations may have contributed to raising public awareness: three local newspapers (the Georgia Straight, West Ender, and Vancouver Courier) and CBC News online referred to the campaign although only one article actually included one of the images. Without interviews of City representatives and a more detailed document analysis, it is not possible to assess the validity of the alternative visualizations or the impact of the Google Earth images on viewers. The images may have informed current policy, because the City published an amended appendix of the "Vancouver Views" report [45] before the revised General Policy for Higher Buildings was approved [46].

Figure 2. The colored buildings are not proposed yet, but with the change of height regulations, such buildings will become possible; the color-coding refers to the City report and marks different possible developments (Bohus 2011; © 2010 Google, Image © 2011 DigitalGlobe, Image © 2011 Province of British Columbia, Gray Buildings © 2008 Sanborn, Image © 2011 IMTCAN)

3.2.4. Discussion

The Vancouver Views example demonstrates the potential of Google Earth to merge user-generated content visualizing a citizen group's point of view with existing Open Data, provided by the City, and Google's own data, in this case a high quality 3D model of the downtown buildings [47]. The use of Google Earth facilitated access to visual information, as well as data display from multiple perspectives. However, despite the accessibility of Google Earth itself, the actual implementation still requires considerable expert knowledge to prepare and transform the geodata, model the 3D buildings and calculate the view cones. While there is anecdotal evidence that the visualization might have impacted the policy making process, it is not possible without more data to directly link the amended City Report to the grassroots campaign or to distinguish the role of the Google Earth visualizations from WEN's other efforts.

4. Case Study: The Kimberley Climate Adaptation Project (KCAP)

Unlike the grassroots examples, participant responses have been scientifically evaluated in the KCAP case study [12]. Therefore, the KCAP allows a more detailed analysis of virtual globe potential to raise interest and awareness and provide a more representative 3D model than static landscape visualizations (Table 1). The KCAP case study was conducted by four of the authors from the Collaborative for Advanced Landscape Planning (CALP). The project included a strong visualization component, as well as policy development and recommendations, and immediate and longer-term scientific evaluation of the process and visualizations. It thus begins to answer, through evaluative research, questions about the response to virtual globes in public planning processes raised in the literature (Benefits 2 and 3 in Table 1) and the two previous introductory examples.

4.1. Context of the KCAP

The Kimberley Climate Adaptation Project was a stakeholder-driven climate change process looking at local climate change impacts and adaptation options, that included local citizens, municipal staff, regional advisors, and a university research group [5,48,49]. A key element of the KCAP was a participatory local climate change visioning process, with multiple facilitated stakeholder workshops. The process lead to a public open house in which local climate change impacts, community vulnerability and resilience across different development scenarios, and possible mitigation and adaptation actions, were presented and discussed. Funded by the Real Estate Foundation, the Ministry of Community and Rural Development, and the Swiss National Science Foundation, with pro bono climate modeling by the Pacific Climate Impacts Consortium (PCIC), CALP contributed to the KCAP process through the integration and spatialization of climate change and other data for Kimberley, presenting the material in various media and types of visualizations, and evaluating process and tools.

4.2. Modeling and Visualization Workflow

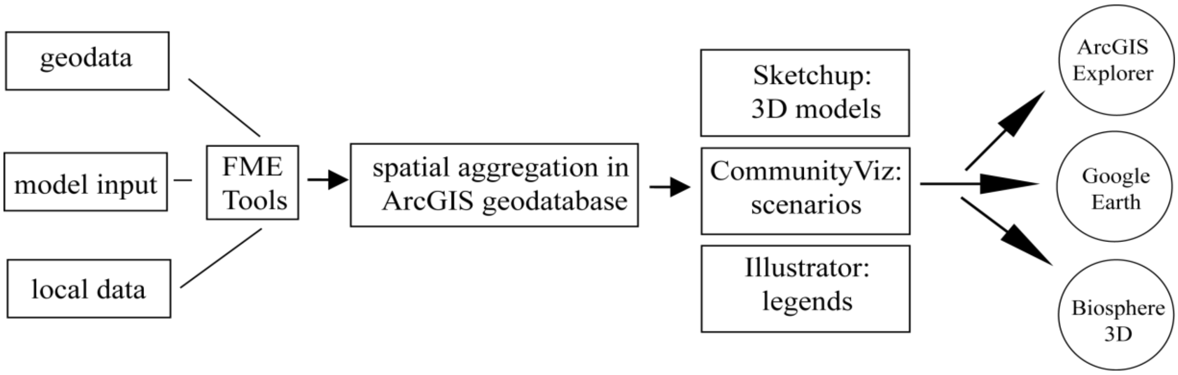
The novelty of the following approach, compared to conventional landscape design workshops [50], is that visualizations of drivers and scenario narratives are aggregated in a virtual globe as a data-driven, interactive, multi-dimensional and comprehensive 3D landscape model that is used as a shared communication platform. The virtual globe model can be used interactively, or still images and animations can be taken for use in other media such as presentations and posters.

Development scenarios for potential future residential buildout in and around the town of Kimberley were modeled using CommunityViz Scenario 360°. The first build-out was based on existing land use zoning, Official Community Plan land use designations, approved land development proposals and pending development applications, including several large areas outside the town core. Assumptions were made about the rate development would occur within these areas over time, with the different stages of development depicted visually as high level oblique views. A second build-out scenario assumed compact infill development. These two scenarios were presented as both static views from key viewpoints, and as animations, depicting the rate and extent of growth over time.

Vulnerabilities associated with urban growth, given current trends and practices, were modeled based on local development scenarios and downscaled climate change projections. Overall, four local climate change related impacts or sectoral vulnerability models were integrated in GIS, each of which was visualized in Google Earth: downscaled hydrological modeling for snowpack changes with climate change (from PCIC); current potential flood areas within the City (based on an older municipal flood study); regional mountain pine beetle susceptibility (originally modeled by CALP, with modeling from the Ministry of Forests, and forecast under climate change by CALP); and, the potential spread of a forest fire with an ignition point in the Nature Park west of Kimberley (modeling from the City's fire consultant). The models are further explained in Schroth *et al*. [51].

The visualization workflow (Figure 3) was kept as simple and accessible as possible to make it replicable for other small communities. Google Earth was chosen as the main presentation medium because it is widely accessible, making it potentially replicable in the future for other smaller communities. In addition, the virtual globes Biosphere3D (B3D) and ESRI ArcGIS Explorer were used as additional tools because B3D is open-source and specializes in the representation of vegetation, and ArcGIS Explorer is well integrated with ArcGIS. Feedback from two sessions with stakeholders, the city planner/councilors, and the KCAP facilitator led to a third round of data gathering, modeling, analysis, and synthesis, and improved 3D visualizations for the final Public Open House in June 2009.

Figure 3. Visualization workflow in the KCAP [48]. FME Tools convert data from one format to another; in this case, from multiple sources such as CAD into ArcGIS.



4.3. Survey and Interview Methods

A mix of quantitative and qualitative methods was applied during the final, public, KCAP open house in 2009 [48]. First, pre-/post questionnaires were distributed before and after the open house to capture changes in individual awareness and understanding. In the questionnaires, participants were asked to rate the benefits of the visualizations in general and then, to rank (a) slide presentation; (b) 2D maps; (c) posters; and (d) the mediated presentation in Google Earth. The ranking provided self-assessed data showing which percentage of participants favored which media and how the virtual globe was ranked in comparison to non-interactive presentation media. Second, 17 in-depth guided interviews were conducted with stakeholders and community members using an interactive 3D Google Earth model of regional climate change impacts and possible adaptation and mitigation scenarios directly at the public open house. Participants were recorded on video while using Google Earth and the analysis of the interviews was related to the actual video recording (cf. data triangulation [52]). A year later, eight KCAP participants were interviewed again to investigate long-term policy and implementation outcomes. The evaluation of the overall planning process and the long-term outcomes will be subject of future publications.

4.4. Modeling and Visualization Outputs

The storylines A) Kimberley Adapts (focus on adaptation) and B) Low Carbon Kimberley (focus on mitigation and adaptation) guided data collection, modeling a future urban development and mountain pine beetle spread, and provided the script for the Google Earth visualization. As part of this paper, it is only possible to show a selection of images; refer to Schroth *et al*. [48], Pond *et al*. [5], and future publications for further examples. The various themes were also printed on posters, combining the images with explanatory texts about the underlying scientific assumptions, data and modeling. Figure 4 shows current conditions around the City of Kimberley, Figure 5 shows parts of the proposed urban extension in the Kimberley Adapts scenario, Figure 6 the outcome of a forest fire spread model, Figure 7 to 9 various adaptation options.

Figure 4. Overview of Kimberley, as seen from south to north: The Nature Park and ski hill are in the west, the watershed is in the northwest, the mining site is in the north, the proposed Taylor's Mill development is in the Northeast. Industrial brownfield sites from the mine ore processing are in the east (Schroth 2009; © 2009 Google; image © 2009 Province of British Columbia; image © 2009 TerraMetrics).

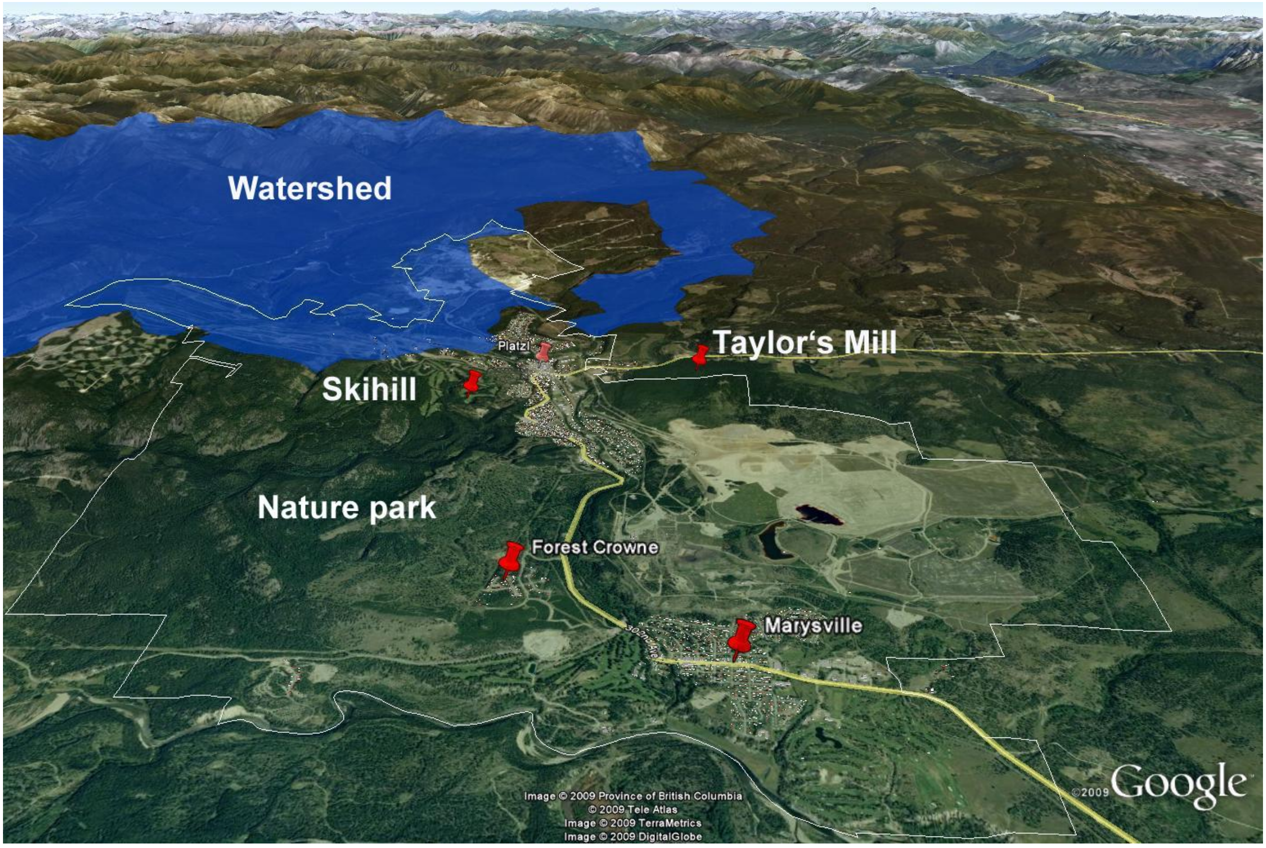


Figure 5. Aerial and perspective view of the proposed Taylors Mill development site: new urban development is represented as grey massing models on the hilltop; white and colored models depict existing development (Schroth, Campbell 2009; © 2009 Google; image © 2009 Province of British Columbia; image © 2009 TerraMetrics)

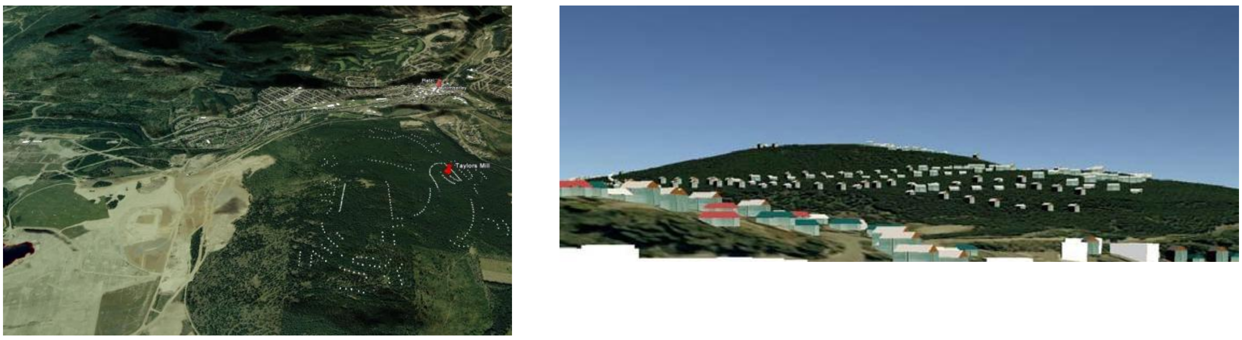


Figure 6. Farsite fire spread model, visualized as 2D map with the model software by the City's fire consultant (**left**) and spatialized in Google Earth (**right**) together with the 3D buildout by CALP (sources: Bob Gray 2009 (**left**); Schroth 2009, © 2009 Google; image © 2009 Province of British Columbia; image © 2009 TerraMetrics (**right**)).

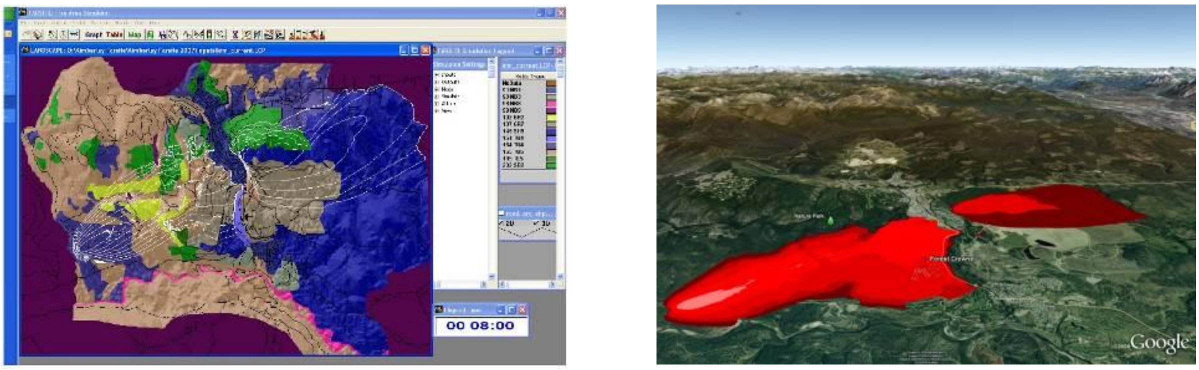


Figure 7. Recommendations for the location of public transport stops in the Low Carbon scenario (Schroth and Pond 2009; © 2009 ESRI ArcGIS Explorer; orthophoto © 2009 USGS).

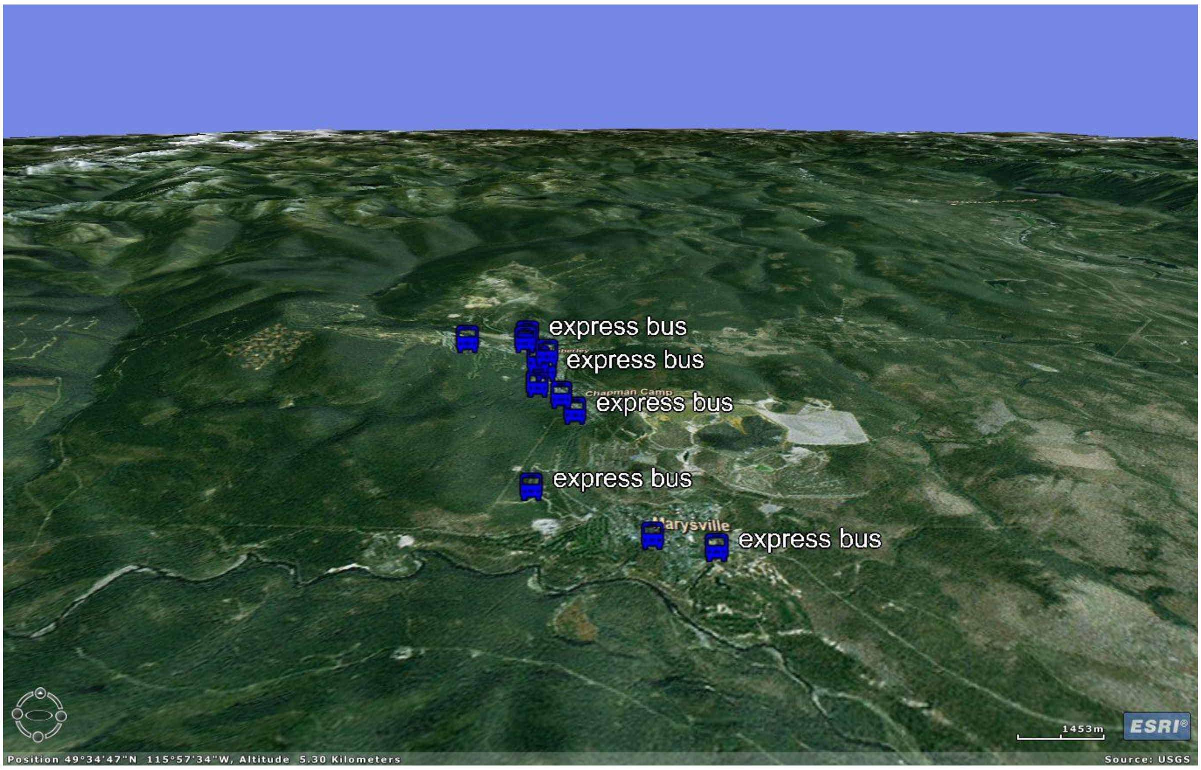
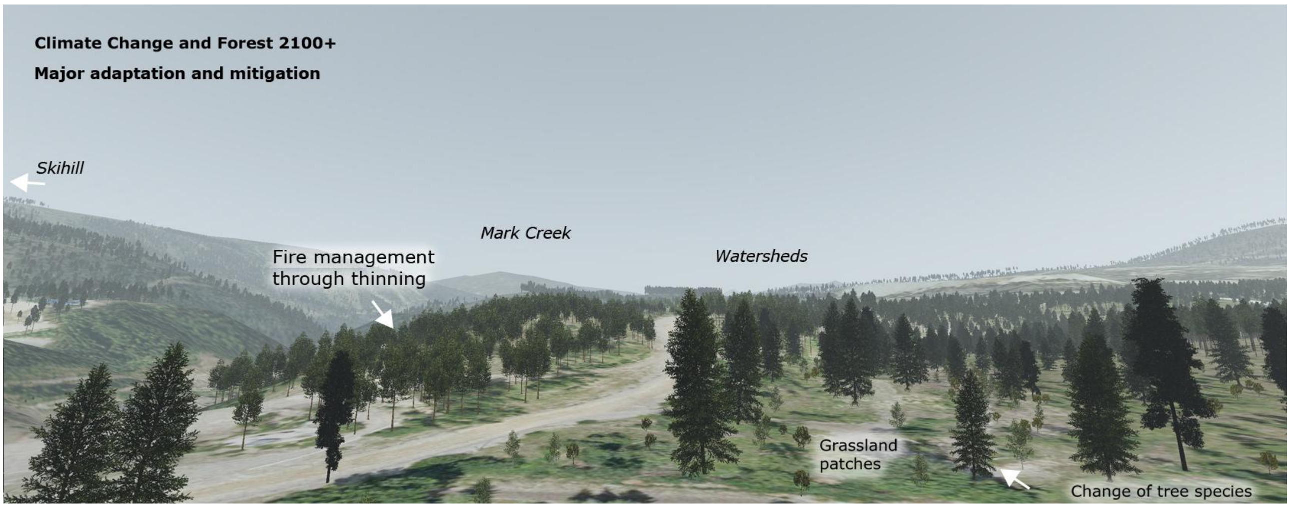


Figure 8. Hand-drawn design sketch, visualized in Google Earth (Pond and Muir-Owen 2009, © 2009 Google; image © 2009 Province of British Columbia; image © 2009 TerraMetrics).

Figure 9. Adaptation and mitigation measures in sustainable forest management; visualized in Biosphere3D with Flora3D tree models (Schroth 2009, with thanks to Paar, Schliep and Ernst from the Biosphere3D community [49]).



Most of the proposed development zones are vulnerable to wildfire. Forest fires are an integral part of the landscape ecology of the Kimberley area, and have threatened the town before. A plausible impact of climate change is the extension of the fire season. Thus, CALP visualized the spatial outcome of a fire spread model from the City's fire consultant in 3D and over time (Figure 6) in order to illustrate how fast a forest fire could take out the evacuation routes: the first highway exit is taken out after four hours, and the second after eight hours. When combined with the buildout model, it becomes obvious that the new low-density development of Forest Crowne and Taylor's Mill, with a large increase of urban forest interface, are more vulnerable than the current city or other, denser developments with less forest interface.

4.5. Policy Outcomes

The KCAP, through the stakeholder and community workshops, produced more than 70 recommendations for climate change mitigation and adaptation, some of which were informed by the visualizations in Google Earth and Biosphere3D. Figure 7 shows possible tracks for public bus transit, Figure 8 a landscape design for flood-proof green space and infrastructure in the city center, and Figure 9 possible visual outcome of sustainable forest management practices adapting to climate change. It is not possible to link policy outcomes exclusively to the case study project because we are not looking at a controlled experiment here, but at a planning process that is informed through multiple stakeholders and policies. Nevertheless, follow-up interviews with key decision makers showed that at least six projects in advanced planning state for implementation were informed by it. In addition, three operational changes were initiated; one outreach event followed the KCAP; and five policy changes, e.g., a new by-law and follow-up studies commissioned by the City, may have been informed by the KCAP.

4.6. Evaluation of Visualization Rankings and Responses to Virtual Globes in KCAP

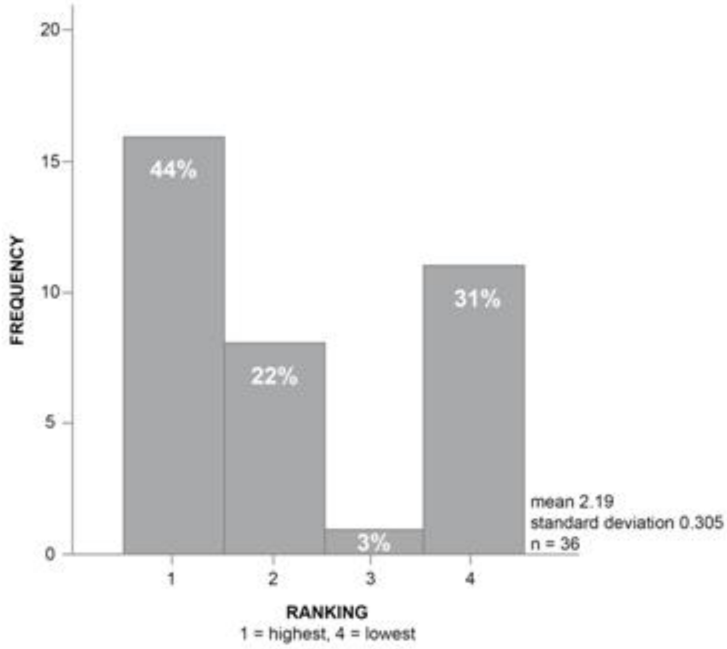
The quantitative rating of visualization benefits and ranking of visualization media types in the post questionnaire, handed out at the KCAP public open house, asked respondents to compare 2D maps, posters, the PowerPoint slide presentation and the Kimberley 3D virtual globe (Google Earth) by ranking them in the order from 1 (best) to 4 (last): "*During the open house, you saw various forms of visualizations. Please rank those visualizations you have seen, in order of importance to you if you were involved in making a comment on a planning proposal.*" n = 38 responses were received including 2 invalid responses (Table 2).

Table 2. Medians and means of ordinal rankings of different media, n = 38.

	N (valid)	Min. rank	Max. rank	Median rank	Mean	Std. Dev.
Posters	38 (36)	1	4	2	1.94	0.826
Virtual globe	38 (36)	1	4	2	2.19	1.305
Presentation	38 (36)	1	4	3	2.83	0.775
2d maps	38 (35)	1	4	3	2.86	1.167

Interestingly, the virtual globe was ranked first 16 times and ranked last 11 times, showing a bimodal distribution (Figure 10). The posters were ranked first 12 times and ranked last only once. Interestingly, the 12 respondents who ranked the posters first, ranked the virtual globe fourth on average (mean of their globe rankings = 3.083, median = 4, std. dev. = 1.165). The results suggest that respondents rating the posters higher gave lower ratings to the virtual globe. In contrast, respondents who gave higher ratings to the virtual globe also gave a higher rankings to the posters: in their responses, posters received a mean of 2.125 and a median of 2 with std. dev. of 0.5. Considering that the posters presented more information at once, whereas virtual globe users had to explore the information through interaction, possible explanations could be that respondents who like the posters have a non-interactive learning style, or there could be digital tool barriers. The virtual globe might also provide too much simultaneous visual information at once, thereby increasing the cognitive load beyond user comfort. On the other hand, virtual globe users who preferred to explore the information interactively also, on average, liked the poster. An alternative explanation might be that expert users with advanced spatial skills preferred the posters because they provided a higher information density at first glance. Unfortunately, size and composition of the sample (*n* = 36) were not sufficiently large to explore group differences on the basis of age, gender or profession with any confidence.

Figure 10. Graph showing the bimodal results from the ranking of virtual globes as compared to posters, presentation and 2D maps (*n* = 36).



Based on these findings, it is suggested that another explanatory presentation format is needed in addition to virtual globes in order to meet the learning styles of all respondents. Based on these findings, it is suggested that another explanatory presentation format is needed in addition to virtual globes in order to meet the learning styles of all respondents, in keeping with the mediated use of 3D landscape visualizations in Salter *et al*. [24].As the average ranking of the posters was very good, they seem to be a suitable complement to the virtual globe.

4.6.1. Responses to Virtual Globes

The results of the following content analysis are based on the coding of the video recordings, qualitative, open questions in the post questionnaire (*n* = 25; 25 out of 38 respondents added comments in the open question sections), and qualitative in-depth interviews directly after the public open house (*n* = 17).

Stakeholder interviews confirmed the quantitative questionnaire findings from the process feedback that the visualizations raised awareness and facilitated understanding of climate change impacts and mitigation/adaptation options. "I thought the benefits were wonderful because you could really see it and it was exciting. The ones that were of Kimberly, because Google Earth is quite new to me. I haven't played with it very much. So, I was just amazed with the technology and how, to be able to see Kimberly as a whole and put in the different scenarios and, and … [see] different consequences with different scenarios" (local politician).

4.6.2. User Orientation

Twice, users as well as CALP team members got lost in 3D space because handling was sometimes cumbersome and there were few embedded navigational constraints. The usability of virtual globes could further be improved through more constraints and "smart navigation" [53] that guides the user. However, it helped that Google Earth provides bookmarks which enable re-orientation within the virtual globe when a user 'gets lost'. They can also re-orient by re-selecting a layer (observations from the video recordings).

In order to choose different views, orientation is crucial. Various landscape elements are mentioned in the transcriptions. It is particularly interesting that two stakeholders orientated with regard to features such as the city's administrative boundaries, features usually non-visible to lay people. It should be noted that both stakeholders work with planning documents and therefore are familiar with these administrative features. After summarizing and abstracting all elements used by participants, the following types of landscape elements (Figure 4; cf. [54]), can be distinguished:

- Topographic features (creeks, mountains, ski hill);
- Built structures (city districts);
- Linear built structures (roads, trails);
- Administrative, only partly physical, boundaries (city boundary, watershed boundary).

4.6.3. Presentation and the Use of Different Media

In general, respondents acknowledged the high amount and variety of information at the open house. For example, one respondent wrote that he particularly liked the "amount and quality of information". Feedback indicates that the presentation of information and visualization, i.e., the mix of presentation, scientific posters, and a virtual globe station with a guide and verbal explanations, is very important for enhanced understanding. "I think it's just really good before people go into one of these globes that there's sort of like some introductory material to say what it is and what it isn't. […] just to put it in better context" (workshop participant with expert knowledge).

5. Discussion, Conclusion and Recommendations

5.1. Discussion

Access to and integration of information was improved by using virtual globes and their data. Data access was obviously an issue in the two grassroots examples, because they had limited access to the data of the challenged projects. In the "Vancouver Views" case, user-generated content was modeled, referencing the City's Open Data, and then placed into Google's 3D Vancouver city model. In comparison, the collaboration with Kimberley provided the KCAP with straight forward data access. In the KCAP, non GIS spatial data from the city and modeling outputs from diverse external experts, including PCIC, consultants, and UBC, were brought together, with virtual globes as the shared 3D platform [3,51]. It may be suggested that this integrative power is one of the biggest potentials of virtual globes as tools in landscape planning. However, such integration also requires more inter-disciplinary work among various environmental research disciplines, as Shupeng and van Genderen [26] have argued. Furthermore, it is difficult to assess the quality and the origin of the various data due to the lack of metadata and data quality tools in most virtual globes. However, the visualizations were not made available in an interactive form online due to unsolved issues of data ownership and liability, as well as concerns about unmediated use and potential misunderstandings. The challenge now is to build reciprocal processes that validate data, to develop collaborative networks of institutional, business, and community stakeholders, and to solve the related legal issues [3].

The landscape visualization literature, e.g., Al-Kodmany [29], had previously shown that 3D landscape visualizations can raise interest and awareness. The quantitative ranking in the KCAP showed that this is particularly true for virtual globes: Virtual globes caught the interest of most people, but it also evoked a bimodal response, with people either ranking it very high or very low. Qualitative data from the KCAP shows that the virtual globe visualization made intangible issues such as future climate change impacts tangible and helped the understanding of complex relationships between different themes, e.g. between mountain pine beetle spread and the risk of debris floods [51]. The qualitative interviews provide hints that some participants ranked virtual globes significantly lower because they found the underlying assumptions and explanations easier to understand from the posters. Previous research by Schroth [17] has also suggested that users with expert map reading skills prefer maps and rank realistic landscape visualizations such as the virtual globe imagery lower than lay people do. Future research is suggested to further investigate group differences and the possible impact of different learning styles and the cognitive load of virtual globes [20,21].

In the KCAP case study, affective and evaluative responses have been documented through observations and interviews. In the KCAP, the animated output of the fire spread model evoked a perceptible reaction among the audience at the public open house. Although the data had been known before, the clarification of the visual data, and "seeing" the possible wildfire, symbolized through red color, and animated over time, increased the dramatic impact. Sheppard and Cizek [1] and Phadke [14] raise concerns that such drama could lead to value-laden responses that potentially overwhelm cognitive responses. In this case, the animation was embedded in a wider public discussion with the fire chief at the table so that people were not left alone but could learn more about possible solutions such as fire-smart building improvements.

The issue of representativeness has to be broken down to different scales. Closer analysis shows that different scales and perspectives come with their own limitations: elevated oblique views at a regional scale, including forest canopy of the new 3D trees in Google Earth version 6, provide a rather realistic visual impression due to the "defocusing" and edge detection, *i.e.*, the phenomenon of being better able to detect object edges when an image with the same resolution is reduced in one area [55]. However, the oblique view tends to "underwhelm" impacts, as one stakeholder put it, confirming the concerns by Sheppard and Cizek [1] and by Dodge and Perkins [11] that "when vegetation growth is maximized and visually prominent [here, vegetation growth was not included in form of 3D models but the linear layout of the town required a distant oblique view that minimized the visibility of the buildings.], the result often obscures the built environment, and thus diminishes the presence of people in the landscape" (2009: 498). In comparison to earlier virtual globe versions, views from a ground viewpoint have improved although they usually don't reach the realism of photorealistic visualizations in entertainment or architectural visualization, which can focus on high resolution foliage and objects in small limited views. On the other hand, the zoom feature of virtual globes provides users with a sense of "gestalt" for the context of the surrounding environment.

The findings on interest and representativeness, *i.e.*, that the use of virtual globes sometimes may overemphasize, and sometimes may obscure, visual impacts, depending on scale and the nature of the development, lead to the biggest issue, the risk of misinterpretation. This risk is particularly acute if complex issues shown in virtual globes are not mediated. Dodge and Perkins [11] identify: "the genuine difficulties in properly seeing with satellite imagery, the need for specialized skills of interpreting features and reading off patterns to gain meaning of the situation on the ground. The key problem–you can see it clearly, but what is it that you are seeing?–is not easily solved" (2009: 499). The KCAP shows that embedding and framing the virtual globe model into a facilitated collaborative process [5], using multiple media such as posters, presentations and virtual globes, can ensure better levels of understanding [16,24]. It seems difficult to provide such framing and assistance for interpretation online, but Craglia *et al*. [3] suggest that a great deal could be learned from the multimedia design disciplines.

5.2. Conclusion and Recommendations

The KCAP case study showed that virtual globes are helpful platforms for information integration at scales that are relevant for landscape disciplines, and they can raise interest and awareness. Not all user groups seem to benefit equally, as the bimodal ranking results indicate. For now it is recommended to include a mix of different media in face-to-face planning or design workshops, e.g., virtual globes together with posters. Virtual globes seem to be particularly powerful at regional scales with elevated oblique views, a scale that is often used in landscape planning. At that scale, orthophotos and vegetation appear most realistic as background for modified 3D data although anthropogenic influences might be under-represented. Virtual globes have improved in the representation of ground-based views but more specialized software is still advised to produce ground-based visualizations with higher realism. The strength of virtual globes is to allow seamless zoom between different scales, supporting landscape planning and design across scales and helping the viewer assessing design schemes in their spatial context. A promising workaround for the visualization of landscape architecture designs–a hand-drawn design sketch, georeferenced and overlayed in Google Earth (Figure 8)–was tested in the KCAP and generally received good feedback [15]. Further linking virtual globes with dynamic forest models may also enhance the vegetation realism at small scales.

The process is the key to the successful use of virtual globes as decision-support tools. There are definitely differences with regard to context and types of processes, whether it is a bottom up grassroots campaign, a top-down initiative [12], or in the case of KCAP, a collaborative approach including local stakeholders, citizens, municipal staff, and external experts. The interviews identified some of the barriers why the virtual globe has not been used even more intensively, i.e., technical and usability issues, unclear data ownership and liability issues. If virtual globes include more features for the documentation of metadata and data quality, they will be more suitable for applications in government environments. In contrast, grassroots campaigns are less limited in the promotion of their virtual globe outputs, but they have less access to information and decision-making processes than collaborative approaches.

Virtual globes such as Google Earth can be powerful and rather accessible tools for information integration and visualization in landscape related processes, particularly at regional scales. Virtual globes still have multiple limitations, some of which can be dealt with by embedding them in a well structured, transparent process that follows ethical guidelines [1,56], and addressing different user groups with a mix of complementary media [16]. Then, virtual globes can facilitate access to visual information, raise awareness and interest, and provide rather representative views of landscapes at the regional scale.

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