ENHANCING 3D MODELS WITH URBAN INFORMATION

A case study involving local authorities and property professionals in New Zealand:

Quantifying the benefit of 3D over alternative 2D systems

By

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Abstract

This thesis aimed to reach two principal outcomes: To develop a robust testing methodology that allowed a detailed and fair comparative analysis of the benefit, or otherwise, of 3D methods of information interrogation over alternative 2D methods; and to test the ability for a single model to have multiple user-group functionality.

The research used the examples of two user-groups within the urban planning industry and their typical decision making processes.

A robust testing methodology was developed to investigate the usefulness of 3D in a detailed and focused manner involving individual end-users as participants in a case study. The development of this efficient process assisted the study in moving past the initial visual impact of the models. The method employed a combination of three research instruments: A focus group formed the base from which an urban planning task, questionnaire and guided discussion investigated evidence for the benefit or otherwise of 3D using both quantitative and subjective measures. Two widely disparate user-groups were selected to further test the functionality of a resource to meet the needs of multiple users: city council urban designers and property developers.

The research revealed that 3D methods of information visualisation allow users to develop a greater spatial awareness, increasing their understanding of information, when compared to alternative 2D methods. While evidence for this benefit was established using both quantitative and subjective methods, the research proved that this increased understanding does not necessarily lead to quicker decisions as the 2D group completed the task faster and more accurately than the 3D group. The ability for a single model to have multiple user-group functionality was confirmed as each of two disparate user-groups noted that the availability of the other user-group's information was of positive benefit to their understanding of the proposed development within the urban planning task.

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“The power of spatial information systems can only be realised if such models are full of data and information which can be queried intelligently so that different layers of information can inform different perspectives, thereby adding value to data in ways that are intrinsic to visualisation.” (Batty, 2006)

1 - Introduction

This thesis evaluates the assumption that because 3D interactive environments convey better comprehension of space, depth and height than alternative 2D methods, the overall decisions that can be made using the information contained within them is enhanced. 3D models commonly have a degree of seduction or hype associated with them, when compared to their alternative 2D counterparts (Gott, 2003). Their immediate visual impact is often superior because of the presence of the third, spatial dimension. This spatial dimension enables users to develop an enhanced spatial awareness, “the measured aptitude for perceiving and comprehending relations involving space or extension.” (Oxford, 1989)

This thesis specifically focuses on the effect the mode of information display has on the comprehension of information and therefore the efficiency of the decision making processes of two user-groups in the urban planning industry: urban designers and property developers. By setting a comparable task, the research analyses whether digital 3D models do in fact improve the decision making process, or whether alternative 2D methods are preferable when considering the speed and informed nature of the types of decisions made by these two groups within the industry.

3D data representation spatially enhances data compared to typical 2D geographically represented data. A number of digital models have been developed to explore this human interaction with 3D data. Innovations such as NASA’s WorldWind, Google’s Google Earth and Microsoft’s Virtual Earth 3D focus on the communication of data about the natural and built environment and the interactions between these datasets. During his keynote speech at the Sociedad Iberoamericana de Gráfica Digital (SIGraDi) Conference at the Universidad de Chile, Santiago, (November 21-23, 2006) Professor Michael Batty, Director of the Centre for Advanced Spatial Analysis (CASA) at the University College of London, spoke of the incredible speed in the development of digital city models. He presented, as a particular example, the CASA Virtual London model. This 3 dimensional (3D) digital model represents a range of digital information sets, from real time traffic flow and subsequent air pollution, to flood predictions as a result of polar ice caps melting. The digital model extends some 20 square kilometres and manifests itself as a collection of buildings, terrain and imagery, with the main focus being the "communication and dissemination to several possible constituencies or audiences" of the various overlaid information sets which populate the model (Batty, 2007). Professor Batty highlighted that the development of any visual, spatial model may only truly be successful if the information it contained could be interrogated in multiple ways, by multiple users. This ability for a single multilayered 3D model to meet the needs of a number of different user-groups throughout a variety of industries is a key issue addressed by this research.

The case for a single 3D model was initially evaluated through a simple prototype model of Wellington City, New Zealand (Ryan and Donn, 2005). The research proposed that a single 3D digital model of a city, to which many different information systems could be linked, is a better approach to the needs of the city than many individual models optimised for each information system. It presented four different potential information layers within a small block of the city (Figure 1.1): a rendered visualisation of building textures; Wellington City Council District Plan height restrictions expressed as interactive 3D extruded blocks of building sites; daylight and shadow analysis integration; and colour coded "plots" of property values.

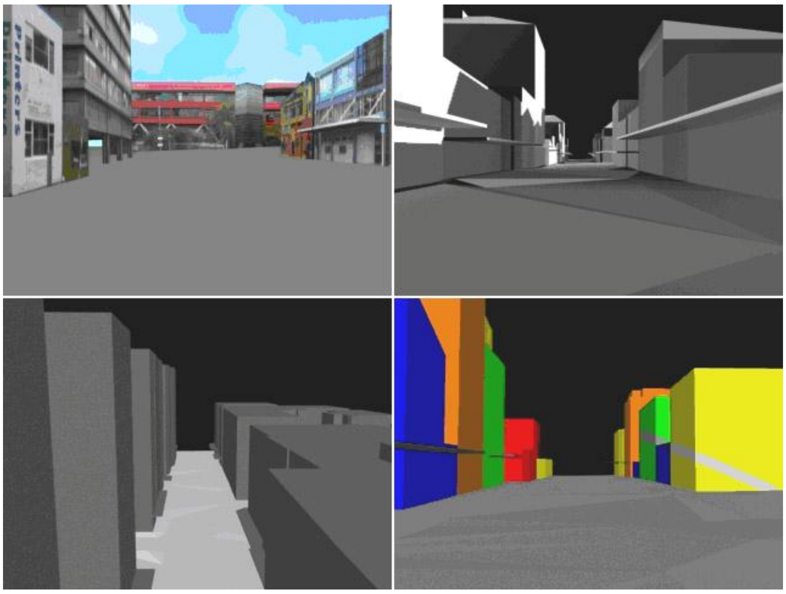


Figure 1.1: Prototype Wellington City model, including (clockwise from top left) textures, shadow analysis, property values, District Plan height restrictions.

The development and delivery of the prototype model was analysed in regards to how complex, costly and time consuming it may be to exploit one base model for several purposes; and also therefore how beneficial, affordable and potentially successful a single model may be. While the research confirmed there was huge potential for the development of such a model and collated overwhelming positive feedback from prospective user-groups, it revealed a need for a focused study on where the benefit of these 3D methods lies over alternative 2D methods. This thesis therefore both continues this previous work, and plays an important role in filling a gap in the field – quantifying the benefit, if such a benefit exists, of 3D over 2D.

The approach taken for this research was to develop a robust and efficient testing process which enabled the study to get past the initial seduction and hype associated with the visual impact of 3D models, and provided a focused analysis of their usefulness. A case study methodology involving a small and select sample of participants from the two urban planning industry user-groups allowed an in-depth analysis of the impact 2D and 3D had on their typical decision making task requirements. A larger study, incorporating more participants as representative groups and using broader research instruments, would have risked being unable to fully scrutinise the models due to the lack of time required to delve past the effect of the initial visual impact. The case study approach was designed as a detailed test of the functionality of the models with individual end-users, rather than a representation of the selected user-groups as a whole.

Three research instruments; tests, surveys and focus groups; were selected, combined and applied in this research to assess the comparative practical analysis of 2D versus 3D as experienced by the two user-groups involved. A focus group methodology was employed as the base instrument, within which the participants completed a guided, timed task with either the 2D or 3D resource. Questionnaires then individually assessed each user regarding their experience with the allocated resource, before all of the participants joined in a guided group discussion.

This thesis discusses the development, delivery and outcome of this robust testing methodology, and presents the approach as a coherent and logical process. It begins with a clear statement of the research outcomes in chapter 2; (1) Testing the benefit of 3D information interrogation, and (2) Testing the multiple user-group functionality. Chapter 3 examines the approaches to 3D data visualisation, including a number of key innovations in the field. Chapter 4 discusses the development of a research design by analysing a variety of appropriate research instruments, and is in turn refined in chapter 5 through the running of a small test case focus group, developed to evaluate the focus group process in order to most effectively run the main 2D versus 3D test. Chapter 6 describes how the two user-groups were selected and presents the results of an initial online user survey, developed to gather essential data about the language and typical decisions of the property developers and city council urban designers. This survey facilitated the design of an appropriate test, carried out during the main focus group. The results of this survey are incorporated into chapter 7, where the test for the main focus group is clearly defined. Chapter 8 follows on by discussing the selection of the location and software for the test and describes how the models were built. Chapter 9 presents the running of the main focus group test, and Chapter 10 evaluates the results, focussing on each of the three components: the task, questionnaire and guided discussion. Chapter 11 and 12 present the conclusions and recommendations for future testing, respectively.

Through the case study scenario of decision making by two widely disparate user-groups within the urban planning industry, the tests developed and carried out in this thesis ultimately provide a detailed insight into where the benefit may lie in using 3D information resources over alternative 2D methods.

2 - Research Outcomes

This research aimed to achieve two principal outcomes: The first was to develop a robust testing methodology that allowed a detailed and fair analysis of the benefit, or otherwise, of 3D methods of information interrogation over alternative 2D methods. The second was to test the ability for a single multilayered model to meet the needs of multiple user-groups within a selected industry, referred to in this research as "multiple user-group functionality". This chapter examines these two outcomes and outlines the methodology by which they were tested.

2.1 - Outcome 1: Testing the Benefit of 3D Information Interrogation

In order to develop a robust test to define whether one form of visualisation has a benefit over the other, first and foremost, the term 'benefit' must be defined. For this research, the benefit lies in whether one or the other of the 2D/3D methods facilitate an enhanced understanding of the information they contain, therefore allowing the users to make quicker and more informed decisions. The following two sub-sections discuss 'enhanced understanding' and 'quicker and more informed decision making', defining the approach adopted to measure the benefit of each.

2.1.1 - Enhanced Understanding

Enhanced understanding is to have a "heightened or intensified" "perception of meaning" (Oxford, 1981), in this case geographic and building information contained within the 2D and 3D resources. An enhanced understanding may often be reached by the addition of extra information or by displaying information in a way that is easier and faster to comprehend. The research methodology aims to test this by creating a typical task for each user-group to complete, using either 3D or alternative 2D methods. The task, discussed in detail later in this thesis, required the participants to analyse a proposed development and make decisions on its impact. While some of the questions had short correct or incorrect answers, some required more descriptive responses, and a number of factors needed to be considered when making the decisions. This research hypothesises that the 3D data would allow individuals to understand the information quicker and in a more spatially-informed way, allowing them to have an enhanced understanding of the potential impacts and therefore be able to have more confidence in their decision. This benefit in enhanced understanding would be evident both in their success or otherwise during the task, in terms of correctness and detail of answers, and from their own personal experience, measured using a survey.

2.1.2 - Quicker and More Informed Decision Making

The two participating user-groups make decisions every day about a number of issues, examples of which are also later covered in this thesis. Whether the decisions using 3D are quicker than when using the alternative 2D methods can be quantified simply by recording the time taken to interrogate the available information and come to the decision. The ability to measure whether the decision is more informed or not is a little more difficult. Informed decision making is the act of reaching an "educated" "conclusion or judgement" from analysis of available information (Oxford, 1981). A more informed decision is often reached due to one or more of the following aspects: access to greater range of relevant information; the ability to comprehend the information better; or, increased time available to consider the decision.

These two issues, of enhanced understanding and quicker and more informed decision making, form the centre from which a robust testing methodology has been developed, incorporating a combination of three research instruments: focus groups, Tests and Surveys. These instruments were adapted to allow a fair, unbiased and complex comparison of the two resources, using a scenario requiring the participants to complete a task involving information comprehension and making decisions. The task was developed to establish whether more informed decisions were being made, by wording the questions in such a way that the quality and detail of the participants' answers would reflect their understanding. One example of this is asking the participants to describe the visual integration of a building proposal. The descriptiveness of their response is a direct measure of their understanding of the proposal.

When comparing 2D versus 3D presentation of information, a number of additional issues must be considered. The selection of software packages used in any comparison is crucial. The method by which they visually display information within them must be consistent in order to ensure they allow comparison and analysis of the communication of the data, rather than of the practical interaction with the data. They should compare 2D against 3D in this respect, not software product X against Y. The choice of task for the two groups must be relevant and use the appropriate "language" of the user-groups. The questionnaires and group discussion topics must be worded to test each participant's personal experience with their allocated resource, and must provide a means of measuring their understanding and decisions. All of these issues are discussed in more detail, later in this thesis.

2.2 - Outcome 2: Testing the Multiple User-Group Functionality

The research focused on two widely-disparate user-groups within the broad urban planning industry, which in itself encompasses a vast range of occupations discussed in further detail in Chapter 6 (Selecting and Evaluating the User-Groups). Time restraints on the 18 month research would not allow analysis of all of these, so two groups were selected to allow an in-depth and focused study, satisfying the term "multiple". Though disparate, they have predicted overlaps in information concerns. The goal was to test the ability of a single model to meet the needs of multiple users.

The groups chosen were city council urban designers and property developers. Both of these user-groups are disparate in their information concerns in that city council urban designers are primarily responsible for evaluating building proposals that change the City, while property developers are generally the ones responsible for creating the proposals. Different sources of information and decision making requirements enable both groups to follow different processes to complete their typical tasks. However, there is also a degree of overlap in the information concerns of the two user-groups, as proven by the running of an initial online user survey (Chapter 6). Both groups are concerned with local City Council District Plan data and how a development may cause impact or effect on the surrounding environment. Participants were selected from the two groups to complete a focused task using a resource containing both common and user-group specific information (detailed in Chapter 8 – Main Focus Group Planning). This was to establish whether there was multiple user-group functionality in either or both of the 2D and 3D resources, through the presence of information aimed at multiple user-groups.

3 - Approaches to 3D Data Visualisation

This research focused on the key differences, if and where they exist, in the communication and comprehension of information displayed in 2D and 3D digital, interactive, multilayered models. In order for this to be a fair test, a solid understanding of both 2D and 3D methods of data visualisation needed to be established. The following section provides an overview of a range of approaches used in today's modern technology to visualise data in 2D and 3D and suggests where the benefit may lie in increased spatial awareness between the two. The conclusions of a number of independent research papers investigating the benefits in participant performance between 2D and 3D display are discussed, highlighting the potential for this thesis to build on these examples by focusing on the benefits in participant understanding and comprehension. Several recent technological modelling innovations, two of which have formed strong precedents in the development of this research; Google Earth (Google), and Virtual London (Centre for Advanced Spatial Analysis, University College of London), are analysed in regards to their contribution to the development of data visualisation and how these models form a base for the 2D and 3D models used in the task.

3.1 - 2D Data Visualisation

In order to successfully analyse the benefit of a 3D resource, the research methodology must be designed to involve an equally functional 2D resource as the baseline task. There is currently a wide range of choice for tools which assist the many user-groups within the urban planning industry to interrogate the specific information they require to make decisions. These tools have evolved significantly over time, but primarily originate from resources such as maps, plans and drawings.

The development of Geographic Information Systems (GIS) tools has seen an increase in the use of digital, interactive, multilayered data resources. GIS allows users to analyse digital data which is geographically spatially referenced as a visual entity – generally as points, lines or regions (ESRI, 1995-2007). GIS tools allow a wide range of interaction in the form of "queries", including the ability to view multiple sets of information at a time and visualise their impact on one another. Currently, GIS is primarily 2D based computer software, with very limited 3D capability. The third dimension is often multiple layers of interactive data, rather than a third dimension of depth or space (Figure 3.1).

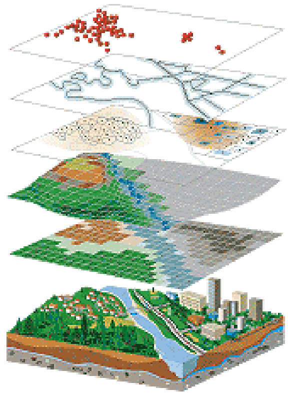


Figure 3.1: Illustration showing the layered nature of GIS information (http://www.gis.com/whatisgis/graphics/gislayers.gif) Last Accessed Feb 2006

Common 2D GIS tools currently used in practice in the urban planning industry as revealed in the initial online user survey (Chapter 6) include Worldviewer, ESRI, Vectorworks, and Microstation GIS applications.

3.2 - 3D Data Visualisation and Spatial Awareness

Most 3D methods of data visualisation originate from their 2D GIS counterparts, commonly containing the same information, with an added third dimension of interaction, consisting of height or depth. This can be explained more simply in relation to planes: 2D models display data in a simple x-y flat plane, while 3D models display data in an x-y-z fashion, creating a sense of volume and perspective (Figure 3.2).

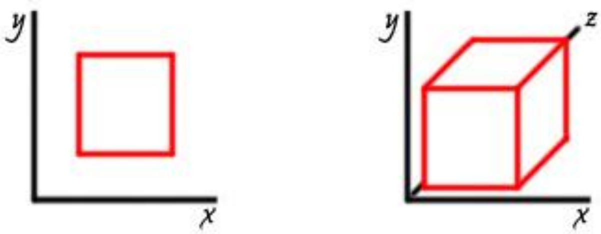


Figure 2.3: 2D model display in x-y plane versus 3D model display in x-y-z planes

It is this sense of volume that allows 3D models to be more spatially complex, assisting users to develop an increased spatial awareness. Spatial awareness is essentially having an increased knowledge of position, relative to other objects in the surrounding environment. However, this increased spatial awareness can give 3D models a significant advantage over their 2D counterparts, in relation to their immediate visual impact. This advantage often means that 3D models have a superior level of seduction or hype, a "wow" factor, which can distract from the model's actual ability to communicate data. In establishing a robust testing methodology, it was essential to develop a process that allowed the analysis to move beyond this seduction, and to focus on the success or otherwise of the communication of data.

There are a number of independent research papers which both support and reject the claim that 3D methods increase spatial awareness and are a more powerful way to communicate information to people than 2D. In a study involving visual systems for the US Navy, it was hypothesised that 3D display would be more useful for understanding the shape of objects, while 2D display would be more useful for understanding the relative positions of objects (St. John, Oonk and Cowen, 2000). The research proved their hypothesis and they stated that "The main advantage of 3D perspective views, is the capability to easily convey the shape of complex objects". A research test of graphical interfaces focussing on the ability for 3D to assist spatial memory, found that "subjects performed significantly better using the 3D display" (Tavanti and Lind, 2001). One study addressing the benefits of presenting abstracted data in 3D to improve communication of information, showed "that structured 3D motion and stereo viewing both help in understanding… providing strong reasons for using advanced 3D graphics for interacting with a large variety of information structures" (Ware and Franck, 1996). However, an evaluation of the effectiveness of spatial memory in 2D and 3D virtual environments revealed that "although it is tempting to believe that moving from two- to three-dimensional user interfaces will enhance user performance through natural support for spatial memory, it remains unclear whether 3D displays provide these benefits" (Cockburn, 2004). These papers focus primarily on testing to establish if there is a benefit in the mode of display. This thesis builds on these papers by testing to establish if there is a benefit in the understanding of the data displayed, enabling quicker and more informed decisions.

3.3 - 3D Digital Modelling Innovations

Over the last 5 years a number of 3D digital information systems have been developed, suggesting that there is growing demand and preference for these types of models, particularly considering that the data displayed within these 3D models is generally already displayed in alternative 2D GIS. Some of the more notable systems include the Centre for Advanced Spatial Analysis (CASA)'s "Virtual London", the National Aeronautics and Space Administration (NASA)'s "World Wind" and software giants Microsoft and Google's respective models, "Virtual Earth 3D" and "Google Earth". All of these systems consist of the same basic format – a 3D textured base model with multiple layers of additional interactive data draped over the terrain.

In NASA's case, they have created a visually rich digital Earth with satellite and Shuttle Radar Topography Mission data, allowing interaction with a number of different "views" of Earth data (Figure 3.3). Blue Marble is a "full colour copy" of the Earth taken by their satellites. LandSat7 consists of a detailed high-resolution collection of satellite images from 1999-2003. SRTM incorporates elevation data obtained from the Shuttle Radar Topography Mission with the LandSat7 imagery to create a 3D interactive environment. MODIS or Moderate Resolution Imaging Spectroradiometer is a catalogue of natural hazards, updated daily, including fires, floods, dust, smoke, storms and volcanic activity. GLOBE is a colour-scaled map representing temperature, rainfall, barometric pressure or cloud cover. World Wind is an "open source" program, allowing anyone to add or "mash-up" any new imagery or data into the model. The purpose of having the Earth open source is to enable quality development and review which builds on top of NASA's base model, by the actual users themselves. Integrating the needs of the various user-groups is a key consideration when creating a successful information resource (NASA, 2006).

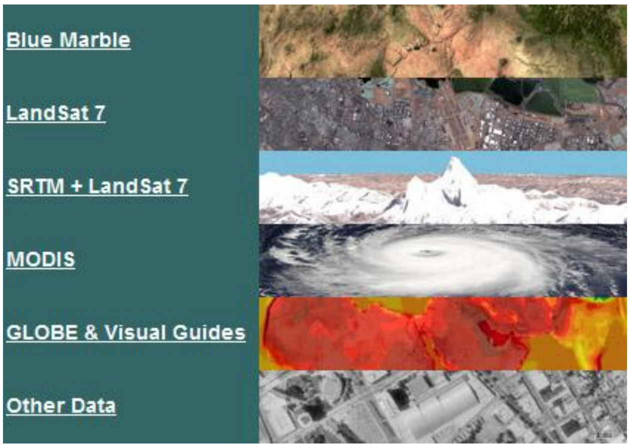


Figure 3.3: NASA's World Wind Earth data

(http://worldwind.arc.nasa.govt/) Last Accessed May 2007

Microsoft's Virtual Earth 3D is a similar system, originating from their Live Maps digital map system consisting of a hybrid of aerial photography and maps (Microsoft, 2007). Virtual Earth uses NASA's Blue Marble imagery as a base, upon which users can navigate through the maps and search for addresses and businesses within cities, some of which have detailed 3D buildings and landmarks (Figure 3.4).

Figure 3.4: Microsoft's Virtual Earth 3D – Las Vegas

(http://www.spatiallyadjusted.com/) Last Accessed May 2007

CASA's Virtual London and Google's Google Earth are two key precedents in the evaluation of current 3D data visualisation models, with Google Earth being primarily an open source model, allowing an abundance of user-added information, and Virtual London being a closed source model, designed with complex and specific environmental and urban related tests and analysis in mind. Successful aspects of both models in regards to information layers and data interaction were used to form the base from which the 2D and 3D task models were created.

3.3.1 - Closed Source: Virtual London

The University College of London has established a research team within the Faculty of the Built Environment called The Centre for Advanced Spatial Analysis (CASA – http://www.casa.ucl.ac.uk) The team is currently made up of 10 experts from a number of disciplines, including archaeology, architecture, cartography, computer science, environmental science, geography, planning, remote sensing, geomatic engineering, and transport studies, with research focused around emerging computer technologies relating to geography, space, location, and the built environment, particularly where multi-user, online environments are involved. One of their major projects, headed by CASA Director, Professor Michael Batty, and Andrew Hudson-Smith is a digital model of the greater London region, called Virtual London.

The model is built up from a number of layers of data. LIDAR (Laser Imaging Detection and Ranging) techniques, which measure heights and distances by use of laser pulses from aircraft in this case, are used to gather terrain and building information about the city. The terrain information is converted into a DEM (Digital Elevation Model) and then textured by draping high resolution aerial imagery over the model. Land parcel information about the buildings on each site is used to extrude the collected LIDAR data in the third dimension, creating solid blocks representing the average heights of the different buildings throughout the city. This forms the basic model, which at 23 November 2006 consisted of 3,601,392 individual land parcels, buildings and objects, which can be turned on and off in any combination due to the additional GIS data associated with each item. For example, buildings newer than 1950 can be turned off, along with buildings lower than 30m, thus showing all the buildings higher than 30m that were built before 1950. The model can then be populated with a wide variety of additional information relating to the attributes and activities of the streets and buildings of London. One major advantage to the digital model is that data can be added relatively easily to represent past, present or even predicted information. Two such examples include the potential effect of the River Thames rising 10m, should the Greenland ice caps melt, and the display of real time air pollution data collected from sensors around the city streets, which shows the impact of nitrogen dioxide build-up, particularly around intersections, bridges and tunnels during peak time traffic (Figure 3.5).

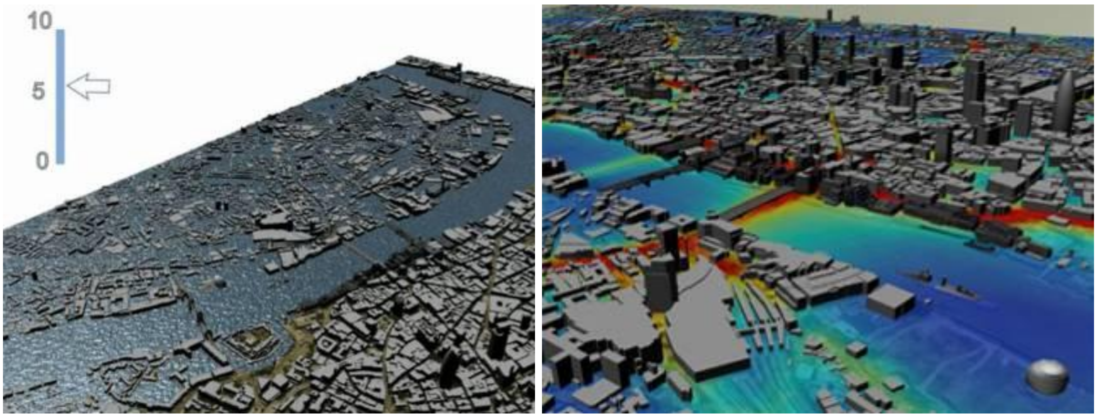


Figure 3.5: Virtual London (left to right) River Thames rise of 10m and Pollution data ("Urban Simulacra" Architectural Design, Volume 75 (6), 42-27, 2005)

The primary focus of the model so far is for use by architects in urban planning and design, but also to use it in the public consultation process via the web (Batty and Hudson-Smith, 2005). As many people do not have access to the types of software and licenses generally associated with creating models like this, the project has tried to use free and accessible modes of delivery, such as Google Earth as a viewer for the closed source data. Michael Batty states that the future holds "enormous challenges in improving, extending and applying methods for visualising the city through virtual city models" (Batty, 2006). CASA's conclusions thus far reveal that there is very slow progress in populating the model with measurably good, useful data. In order for this to be achieved, models must be created and developed in situ with real users (Hudson-Smith, 2005).

3.3.2 - Open Source: Google Earth

Google Earth is a virtual globe of the world, made up of aerial and satellite imagery and 3D terrain data, which allows the user to navigate around and zoom into any city in the world (Figure 3.6).

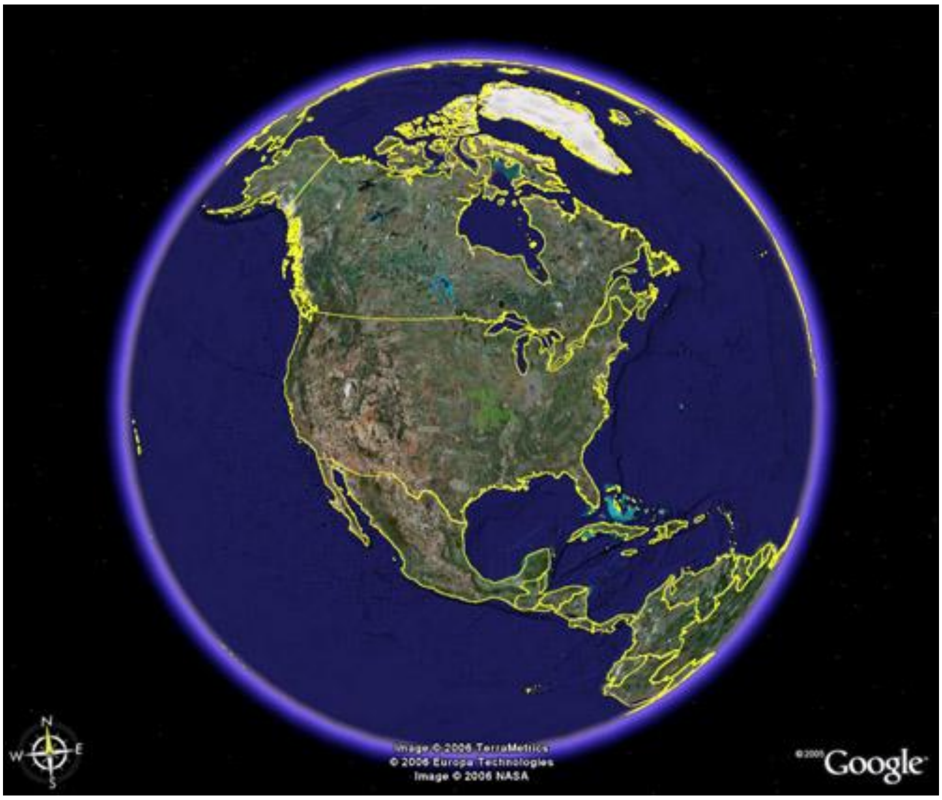


Figure 3.6: Google Earth

(www.earth.google.com) Last Accessed Oct 2007

The basic Earth "viewer" is downloaded (free of charge) to the user's computer hard drive and the selected information is then streamed from Google's massive database. Many of the cities have very detailed imagery, some at a resolution which allows individual people to be seen in the underlying digital photographs walking on footpaths or sitting down on park benches. As the user zooms in, Google Earth streams higher resolution aerial imagery. Some cities also have simple 3D models available. Google Earth has a number of layers, which can provide information about the model. At present they show the location of near-by dining areas (including bars/clubs, cafes and restaurants), shopping malls, banks, grocery stores, pharmacies, gas stations, sports venues and recreation areas, hospitals, schools, churches and cemeteries, and so on. These can all be turned on and off or viewed in combination with each other.

Users can also add their own "placemarks" (small icons which represent a particular location) which can have associated information bubbles providing additional information about the place, links to websites, web cams or any other data available on the web outside Google Earth. The free version of Google Earth also allows users to locally overlay their own aerial photographs, maps or other images. Google Earth PRO (a US$400 version) allows a number of additional features – such as the ability to draw lines and simple polygons, or to import spreadsheets of data, such as a table of placemarks defined by latitude and longitude values. PRO also has a number of optional features available at an additional cost, such as a movie making module, and a GIS import module which can be used to import 3D models or 2D information such as roads, open spaces, land use, and many more. Google Earth is unique in that rather than displaying just one city or a small section of a city, it provides a wider context by inserting the geometry into its exact position in the globe, allowing people from all around the world to better understand the true location of the information (Google Earth, 2007).

Google Earth allows users to placemark any location or add any information they please, which allows a huge amount of untapped potential for growth and development. This potential for large amounts of layered information to be displayed is beginning to be harnessed by Google already; as there became too many restaurants, they split into types (Chinese, Thai, Vegetarian, American etc), and as these types become too populated, no doubt Google staff will split the data further ($10> meals, $10-20 meals, $20> meals etc).

The open source nature of Google Earth has allowed the development of the most fascinating ever-growing forum of dedicated followers: The Google Earth Community (2004). As at 25th January 2007 there were 719,200 members, 1,348 of whom had signed up within the last 24 hours. These members have begun developing a wide range of "hacks" through the open source Google Earth model, which are extra methods of displaying new information within the existing interface, many of which include a database link of some kind. Two such examples are Chicago Crime and Housing Maps.

Chicago Crime (2005-2007) uses Google Earth to provide a method of browsing Chicago's reported crimes. Chicago can be viewed in map (streets) or satellite (imagery) mode, and then different types of crimes can be displayed based on their location of occurrence (Figure 3.7). The crimes can also be displayed depending on their type, date, or district.

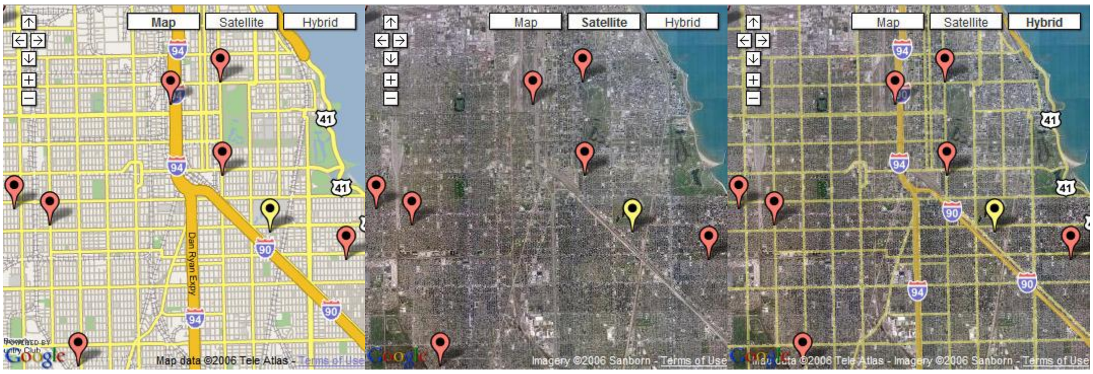


Figure 3.7: Chicago Crime showing crimes (left to right) in map, satellite and hybrid mode (www.chicagocrime.org) Last Accessed Apr 2006

Housing Maps (2007), which uses the same interface as chicagocrime.org, displays houses for rent or sale in most states in America. Users can zoom into a state and view houses of interest based on location or price, and can click on potential purchases to view additional information – such as price, exact address, photos, or the contact email address of the seller or agent (Figure 3.8).

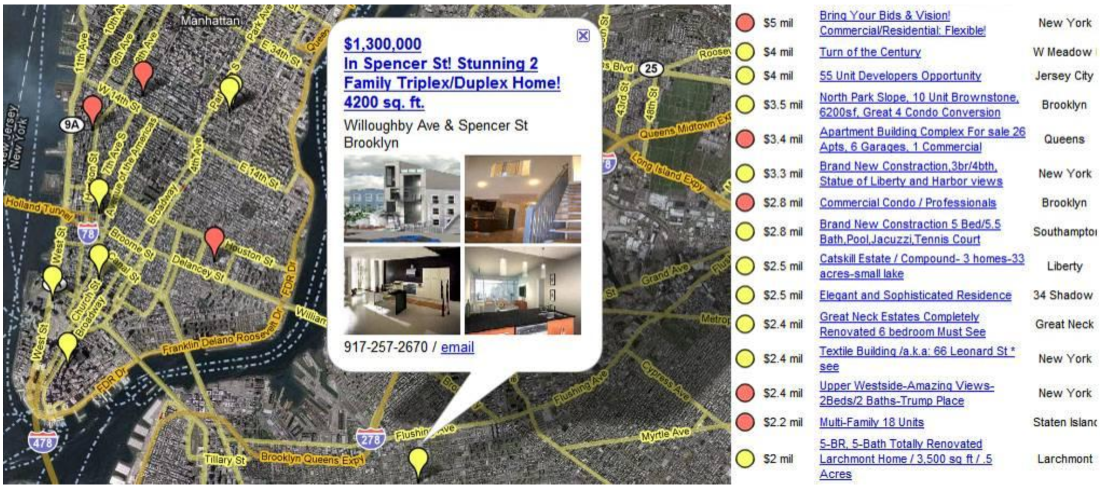


Figure 3.8: US Housing Maps showing houses for sale in New York with US $1mil value plus (www.housingmaps.com) Last Accessed Apr 2006

Other “hacks” include: Tracking the progress of a whale shark’s migration with a GPS device; Real time sunlight, cloud cover and low level wind data; Real time updates of traffic flow; the position of commercial flights above America, updated every 5min; Colour-coded census results; and detailed 3D models with the use of modelling software, SketchUp (Figure 3.9).

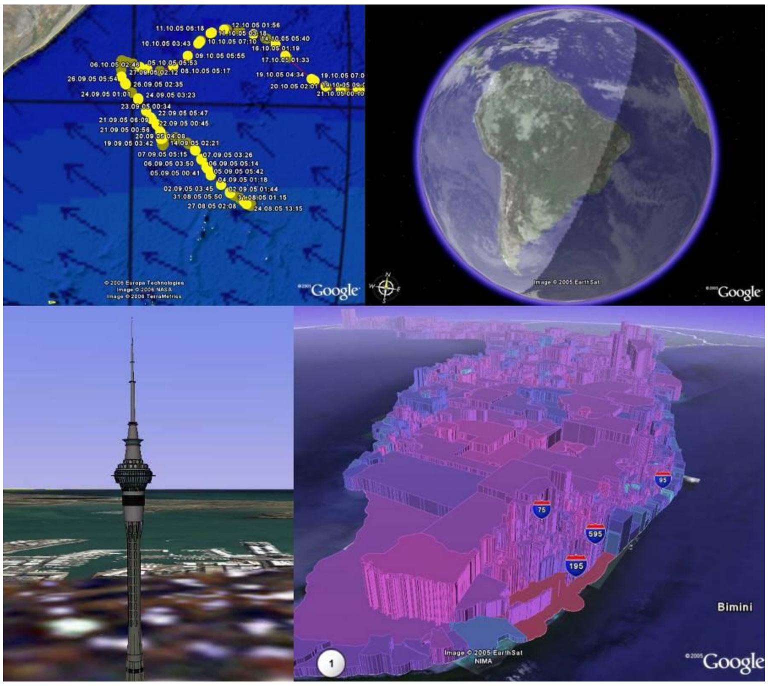


Figure 3.9: Google Earth Hacks, including (clockwise from top left) Whale Shark migration, Real-time cloud cover, Colour-coded Census results for Florida, 3D modelling (http://bbs.keyhole.com) Last Accessed Apr 2006

As of January 2007, the Google Earth Community members have posted a total of 472,196 discussion topics on issues including travel information; history and war zones; “find this place” co-ordinate games; environmental issues; dynamic data layers of user-published information; even an entire section dedicated to sharing 3D models and talking about geospatial issues.

These “hacks” reveal the primary inconsistency with Google Earth – the integrity of the information contained within it. Google allows three methods of information upload; (1) Google loaded and maintained data, usually purchased or collated from various Government departments and aerial imagery companies worldwide and accurate to within a reasonable scale; (2) Google Earth Community added data, consisting of imagery, datasets and hacks created by users of varying levels of geographic ability with often unreliable or uncalibrated sources for their data; and (3) Local user data, which can be virtually anything individual businesses or users can think to add themselves. The open source means that the users always need to be weary of the potential inaccuracies of the information they are viewing, particularly in relation to geographic location and currency.

3.3.3 - Case Study of a Google Earth “Hack” Application

The open structure of Google Earth allowed me to spend three months working with the Wellington City Council to document the process of creating a 3D digital multilayered model of Wellington City for their internal use. The basic model was constructed from Council GIS data. From here, a number of sets of information were overlaid, based on what the Council believed would be most visually useful for their Urban Designers, when considering the data which was most commonly consulted during the processing of typical resource consent applications. The final model consisted of a combination of imagery, 2D and 3D GIS data and additional information bubbles (Table 3.1).

Table 3.1: Wellington City Google Earth model data layers

Aerial Imagery	▪ 1:2000 aerial imagery (2004) of Wellington's CBD
2D GIS Data	▪ Residential Property Boundaries Site outlines divided into inner and outer residential zones
	▪ Roads and Rail Lines Lines representing roads and rail within the greater Wellington region
	▪ Open Spaces Site outlines of parks and public spaces
Simple 3D GIS Data	▪ Existing Wellington CBD Buildings From the Stadium to the Basin Reserve, divided into the Council devised "Quarters": Lambton, Willis, Cuba and Courtenay Quarters, then the remainder of the CBD
	▪ Wellington CBD District Plan Height Zones The CBD was been divided up into height zones (and colour coded accordingly) in the District Plan, with each zone representing a maximum allowable height the site may be developed to. Site outlines were extruded to represent the height they could potentially be developed to.
	▪ Existing Wellington CBD Heritage Buildings All buildings defined as Heritage in the Council District Plan
Complex 3D GIS Data	▪ Wellington Landmark Buildings 10 selected Wellington landmark buildings were modelled in a complex fashion to allow users of the model to locate themselves within the City.
Additional Data	▪ Tagged information bubbles Containing photographs, website links and additional information about buildings and spaces.

By progressively activating each data layer in a cumulative manner, users were able to see a more and more detailed view of the City (Figure 3.10)

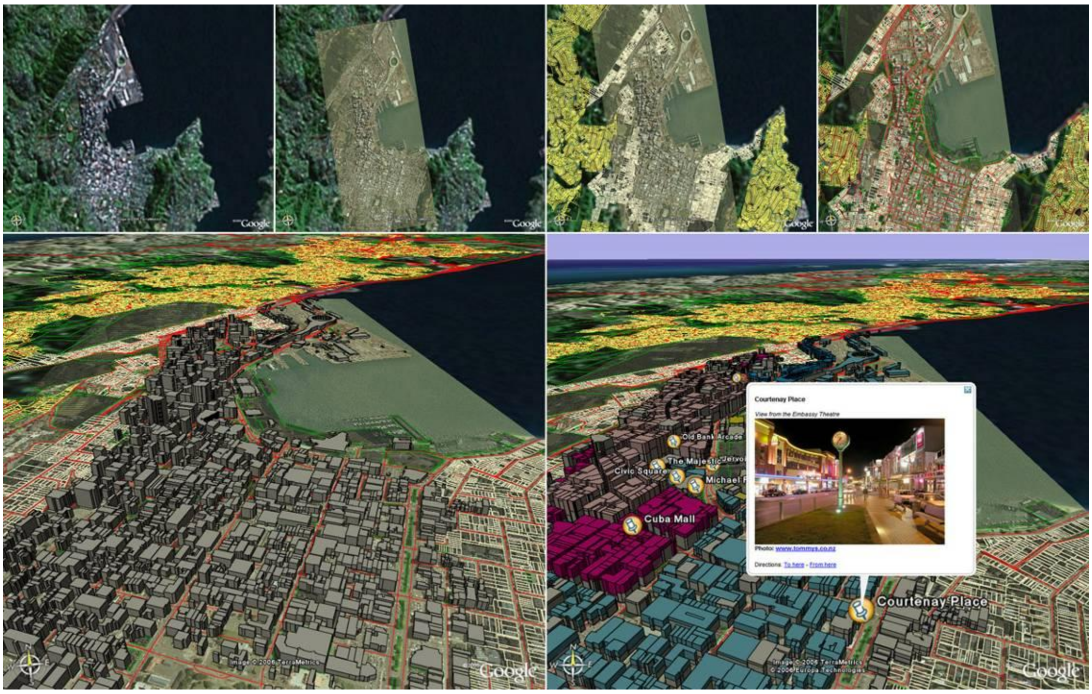


Figure 3.10: Google Earth model of Wellington City, showing the cumulative effect of turning on a range of 2D and 3D GIS data layers

This case study "hack" application created a great digital resource, however, lacked evidence of a measurable benefit of usefulness. It revealed the need to consult directly with end users to establish this usefulness over alternative 2D methods.

3.3.4 - Commercial Developments for User-Groups

Software developers and firms specialising in data visualisation regularly create customised commercial solutions, to communicate information to particular clients and user-groups. Terralink International Limited (TIL), the industry partners in this research, are able to produce 3D virtual reality environments and fly-through animations to display information to user-groups in ways that assist their spatial awareness. Previous models have been used in television documentaries, property development projects, tourism, and criminal investigations. TIL's latest interactive mapping solution is NZ MasterMap, a multilayered interactive GIS database. Users can purchase licenses for up to 14 layers of up-to-date data (Figure 3.11) to create their own unique application, which enables MasterMap to cater for the needs of a wide variety of user-groups (Terralink International Limited, 2004-2007).

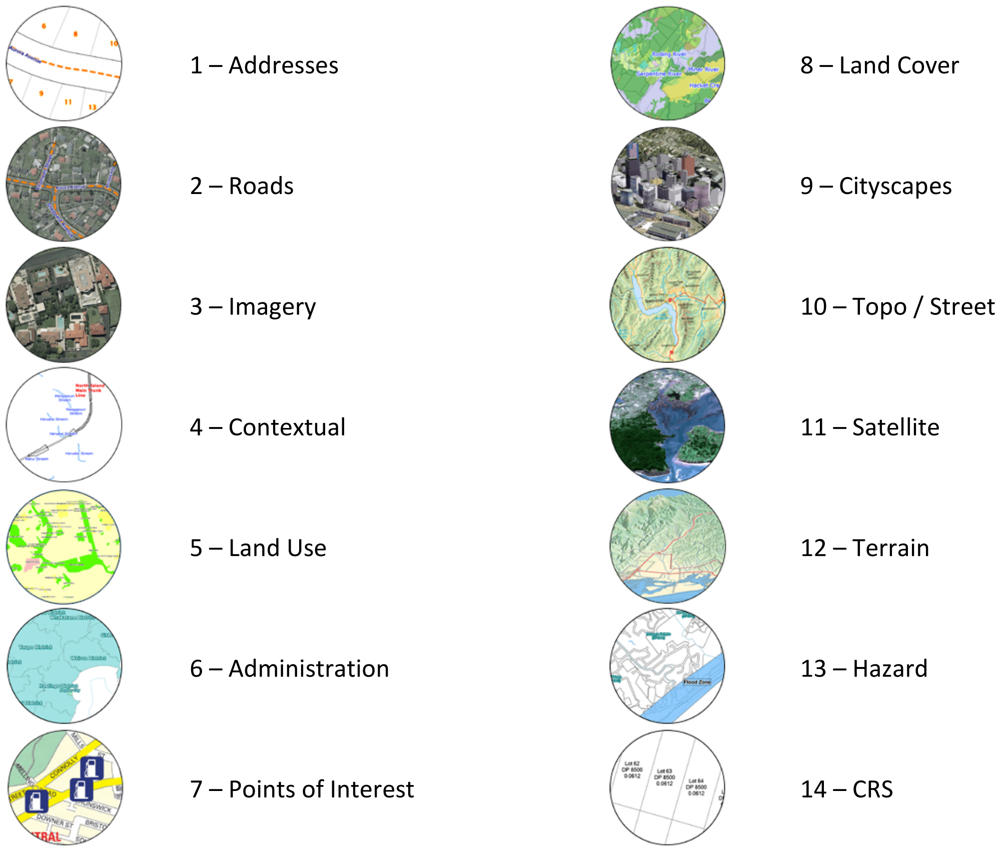


Figure 3.11: Terralink International Limited's NZ MasterMap database information (http://www.terralink.co.nz/products_services/gis_data_services/nz_mastermap/) Last accessed Oct 2007

Layers such as Terrain and Cityscapes are available in 3D, allowing a greater degree of interaction with the data and enabling the communication of existing or proposed developments via a more spatial method.

All of these models and technologies are advancing further every day, with large teams of people working on their research and development (in Google's case, teams of people by the hundreds). While systems such as Google Earth and Virtual London allow user interaction with a range of information datasets, there is a still a lack of proof as to whether these advanced 3D digital, interactive, multilayered models actually have any measurable benefits over their preceding 2D counterparts in relation to information understanding. The major focus of this research lies with what the users do with this information and how successfully they interpret it, which was particularly reinforced by CASA's findings (Hudson-Smith, 2005 and Batty

2006). In this context, a focus on the practical use and comprehension of 2D versus 3D information was measured by the establishment of a robust comparative test, which measured the ability of the models to communicate information and to improve the efficiency of decision making for real life user-groups.

4 - Developing the Research Design

In order to develop a test for this research, the comparative situation of 2D versus 3D needed to be considered. There is a range of research instruments which can be used to analyse real productivity of real people using real design tools, such as observation, case studies, experiments and questionnaires or interviews.

Research such as Cockburn and McKenzie's (2004) "Evaluation of the effect of the Third Dimension in a Document Management System" describes a comparative testing methodology which employed timed tasks and questionnaires. The research aimed to provide both quantitative and subjective evidence for the improvements 3D interfaces may offer in regards to spatial memory. Two interfaces were created containing identical information, with the only difference being the method by which the data was displayed: one 2D flat interface and one 3D perspective interface. The participants were allocated either the 2D or the 3D interface and required to sort a set number of thumbnail images using their own system. They were then asked to rate their confidence regarding how successfully they believed their sorting method would allow them to retrieve information, using a 5-point Likert scale (ie, disagree = 1, agree = 5). The participants then completed an information retrieval task which required them to locate a set number of randomly selected images within their sorted system as quickly as possible during a set time frame. They were then asked to use the Likert scale to rate their confidence regarding how successfully their sorting method actually allowed them to retrieve information. Finally, the participants were asked to communicate their overall thoughts regarding the effectiveness of the interface. The combination of both quantitative testing and subjective analysis addressed the comparative aspect of the research, while providing more than one set of evidence for the hypothesis.

Other examples of research comparing the impact of 2D versus 3D include St John, Oonk and Cowen's "Using Two-Dimensional and Perspective Views of Terrain" (2000) and Tavanti and Lind's "2D vs 3D, Implications on Spatial Memory" (2001).

Both studies incorporated systematic testing instruments which compared the ability of 3D to outperform 2D in identical tasks. In St John, Oonk and Cowen's case, participants completed a task which required them to match images of terrain with viewpoints using one of three randomly occurring conditions: a 45-degree 3D view, a 90-degree 3D view, or a 2D topographic view. Reaction times and errors were collated to analyse the success of each of the participants to match the viewpoints with the each of the conditions. 3D proved to enable better understanding of the shape and layout of the terrain, quantified by faster response times and a higher proportion of correct answers. These notions of using a timed task to compare situations and collate measurable results are strong precedents for the development of the design for this research.

The following chapter outlines a selection of suitable research instruments which are based around the testing and rating methodologies of Cockburn and McKenzie (2004). Chapter 5 – Refining the Research Design, then continues by providing an evaluation of these research instruments to establish how they can be adapted to address the comparative issue of 2D versus 3D, while also allowing analysis of the usability and effectiveness of the two resources with industry-based users.

4.1 - Tests and Examinations

A test or examination is "a procedure intended to establish the quality, performance, or reliability of something" (Oxford, 2005). Tests yield results that can be measured and compared against a baseline, often resulting in a "pass or fail" outcome. In science fields, practical examinations or tests can be set-up and administered under controlled conditions in a laboratory. This is a particularly useful approach to evaluate the usability and the success, or otherwise, of the communication of 2D and 3D information. The main advantage of using a test methodology is the ability to measure the participant's speed by timing the task and to measure their accuracy by analysing the answers or results they come to. One disadvantage of tests and examinations is that they are often time consuming, particularly if the design is such that they can only be completed by one participant at a time. This can be avoided by developing the test to be completed by groups of participants, rather than individually (Wittig, 2000).

4.2 - Surveys

A survey is "an investigation of the opinions or experience of a group of people, based on a series of questions" (Oxford, 2005). Surveys are a method of quantitative data collection which involves asking participants a range of questions in a structured manner, which does not influence or bias their response. A survey is designed to have a standardised format, so that each participant is exposed to the same questions, in the same order, ensuring the results are valid and reliable (Fowler, 1993). Surveys are an appropriate instrument to analyze the individual thoughts of participants, revealing their preferences and opinions in regards to 2D and 3D tools, without influence from others in the research sample. There are a number of advantages to using a survey method: They are generally easy to administer to a large sample of participants; they yield standardised results with very few errors, which can be easily categorised and analysed; and they provide sufficient flexibility in the range of questions that can be asked. The primary disadvantage is that the results of an individual participant's survey depend on emotional factors such as their mood, motivation, memory and honesty at the time of completing the survey. A tired or uninterested participant may give short, brief answers, whereas a motivated and excited participant may give very detailed or even exaggerated answers and thus present themselves more favourably (McKenna, 2000). Other issues include an inability to express themselves or even non-response, which can sometimes bias the overall sample.

There are two types of surveys: Questionnaires, which are administered by the participant on their own, and Interviews, which are administered by the researcher in direct contact with the participant.

4.2.1 - Questionnaires (Participant-Administered Surveys)

A questionnaire is "a set of printed questions, usually with a choice of answers, devised for a survey" (Oxford, 2005). Questionnaires are designed and delivered in a way that the participant can complete them independently of the researcher. The main advantage of this is that a large sample of the population can complete a single survey at the same time, saving significant time and effort on the researcher's behalf. Questionnaires require careful planning during the design stages so that they are straightforward and easy to fill out for the participant, but most importantly the questions are ordered, worded and formatted in a way that the researcher can collate and interpret the answers during post-survey analysis (Sudman and Bradburn, 1982). There are a number of different types of questions that can be asked; Closed questions, give a Yes/No or multiple choice response, which can sometimes frustrate participants if their belief or answer is not represented (ie, Maybe); Open questions, give a worded response and are often time consuming to analyse, usually involving picking out recurring words or themes; and Scaled questions, give a numerical response along a continuum which can be mathematically measured. Consideration to the type of question asked and the resulting answer it will give needs to be carefully thought out, so that the researcher can establish how they will analyse and summarise the data. The questions should follow a logical sequence, usually starting with general questions and then becoming more specific, and each question should not be influenced or biased by those preceding it. It is most successful to test questionnaires before publishing them with non-participants in similar fields to the population sample, to evaluate the layout and responses, ensuring it will yield the required data (Suskie, 1996). Online questionnaires are a popular format for large scale delivery and allow the participation of users from around the county, yielding a broader geographic sample of participants. However paper-based questionnaires are more appropriate in some circumstances, for example to survey an audience on their thoughts after a presentation. The main disadvantage of a questionnaire is that there is not a personal or physical connection made between the researcher and participant, making recruitment difficult and often causing a reduction in response rates.

4.2.2 - Interviews (Researcher-Administered Surveys)

An interview is "a series of questions to a person", "oral examination" or "session of formal questioning of a person" (Oxford, 2005), essentially a survey that is delivered by the researcher in direct contact with the participant. The structure, order and wording of questions in an interview should be considered in exactly the same way as that of a questionnaire, so that the responses can be collated and interpreted (Fink and Kosecoff, 1985). Each participant interviewed must be asked the same questions, in the same order, and preferably under the same circumstances, typically in person or over the phone. Interviews have an advantage over questionnaires in that they sometimes yield more detailed or emotional responses, due to the direct human interaction involved. The main disadvantages are that they are time consuming, as only one can be completed at a time, and that they are not action-oriented, only measuring the participants' opinions.

4.3 - Focus Groups

A focus group is "a group of people assembled to assess something" (Oxford, 2005) and are run via a moderated discussion which allows interaction between the participants on a specific topic. They aim to target a small sample of people who have a particular knowledge or skill, which makes the method a suitable approach for analysing specific user groups concerned with specific decisions. Focus groups are a qualitative research method, most successful when combined with supplementary data collection methods from interviews, participant observation, surveys or experiments (Edmunds, 1999).

Usual group size is around 6-12 people and focus groups are typically held over 1-2 hours. Generally, 4 is the smallest number required for participants and 12 is considered the maximum (Greenbaum, 1993). Small groups of around 4-8 allow each person more time to ensure their personal opinion is well heard, however the size can be sensitive to the dynamics among the individual participants, such as colleagues, friendship pairs, experts, or un-co-operative participants. Larger groups of 8-12 are often harder to control and manage, requiring a higher level of moderation.

The discussion is guided by a moderator, who encourages open dialogue around 2-5 topics or questions, ensuring that the participants do not deviate too far from the predetermined topics. Transcripts are commonly used as a method of data collection.

The main advantage is that focus groups encourage discussion between the participants, rather than discussion with the interviewer, often yielding more honest or natural feedback based on the participants' points of view. Focus group interviewing saves money, but mostly time as it is much more effective to interview many in an hour or two, than 10 people at 1 hour each. They are commonly used as a research method in the marketing industry, where their purpose is to gather feedback and make accurate projections for the success or otherwise of new products or services (Morgan, 1988). However, unlike surveys and tests, focus groups are not anonymous. Being part of a group of those in a similar field can sometimes cause participants to feel pressured to conform and agree or to withhold their thoughts. Hearing a range of different opinions during the discussion can also influence participants' original point-of-view, causing them to change their thoughts on the subject. Analysing the results is also a significantly time consuming process, involving complex interrogation and analysis of the discussion transcripts for statements or occurrences of keywords (Breakwell, Hammond and Fife-Schaw, 1995). These potential issues were analysed and addressed through the running of a test case focus group, discussed in Chapter 5.

5 - Refining the Research Design

A methodology combining both tests and surveys is an appropriate way of addressing the comparative issue of 2D versus 3D, as illustrated by Cockburn and McKenzie's (2002) successful incorporation of these two research instruments in their comparison of the impact of 2D and 3D to assist in spatial memory. Systematic data collection via testing was essential in this research in order to quantify the benefit or otherwise of 3D. Incorporating an in-depth subjective analysis from each of the participants was also important, as the detailed case study nature of the research aimed to focus on the functionality of the models beyond their initial visual impact.

The inclusion of a focus group research method allowed participation from a variety of users and specifically focused on their thoughts about the resources presented to them. Focus groups can also be designed to incorporate additional research instruments, such as Tests and Surveys. One limitation of the focus group method is that opinions can only be drawn from the selected people who attend. However this can also be an advantage, as the method allows targeted research by selecting participants with particular relevant knowledge or skills. These skills make them informed candidates for the tasks and questions, reducing bias as they do not have to learn about the tasks and questions in addition to learning about the tools presented to them. This was of particular relevance to the research, as the focus was on a detailed study of 2D and 3D with individual users from two user-groups, rather to represent the user-groups as a whole. This is discussed in more detail in Section 6.1 – Selecting Two User-Groups.

The following section investigates the focus group research process as a suitable methodology by analysing the running of a small test case focus group, carried out with TIL and their clients. This allowed the process to be evaluated and refined in order to most effectively run the 2D versus 3D focus group. The proposed testing methodology is then established, based on the lessons learned during the test case focus group and incorporating Test and Survey research instruments to develop a process to compare and evaluate 2D and 3D.

5.1 - Test Case Focus Group

A small focus group was run in February 2007 focussing on 3D software package, GeoShow, as a new method for communicating data to a range of user groups in a 3D interactive format. The purpose of this group was to observe the running of such a group in order to better understand issues such as selection and recruitment of participants, running and moderating a discussion, presentation techniques, and the approximation of the time required for creation of models, analysis of data, and the planning and running of the entire process from start to finish.

5.1.1 - The Process

The test case focus group aimed to recruit between 8-12 participants, plus 2-3 extra to allow for people who did not show up. This size was to allow each participant the chance to speak for at least 5 minutes each during a 1 hour discussion. The participants were a select group of TIL clients who were expected to be interested in the topic of the focus group. They were recruited via email and follow-up phone calls. The email did not discuss anything specific relating to the 3D interactive format of display, as it was important to ensure the participants were not pre-empted into forming any opinions before they arrived. However, a rendered still image from the digital model was used to entice interest and hopefully convince the participants to come along.

The test case focus group used a GeoShow digital 3D model of the Queen's Wharf area in Wellington, New Zealand, as a demonstration. The area has a good urban mix of commercial, private, public and industrial activity, along with significant historical interest, public transport routes, restaurants and bars, acoustic considerations and a network of services. It contains the sites of a number of proposed buildings, some already in the early stages of construction, which had been modelled extensively in the past by TIL for other projects. A number of additional data layers were chosen to be displayed on top of the base model, consisting of sea, terrain and detailed textured buildings. The chosen data layers were selected by listing and ranking them in relation to the time constraints involved in their creation and the information interests of the confirmed participants.

The seven participants arrived at 2.00pm on a Wednesday and participated for approximately 2 hours. Mondays and Fridays were discarded as difficult days to run focus groups due to a general lower level of concentration by the participants on these days. Monday is regarded as the busy start to the week for most professionals and Friday is generally more casual and relaxed, as people anticipate the approaching weekend. While a morning (10-12pm) time slot is most preferable, as this is when most participants' concentration levels are at their peak, a mid-afternoon (2-4pm) time slot is also acceptable, as concentration levels are still high and participants have an added excuse to take the remainder of the afternoon off work – a surprisingly effective proposal (Langley, 2007).

The test case focus group opened with a brief introduction from each of the participants in order to establish what they were concerned with in their everyday jobs before the visual impact of the demonstration, which may have abstracted or modified their thoughts. They were asked:

- What visual tools does your business use now?
- What do you imagine technology could do for you and your business?
- What do you hope for?

The GeoShow digital 3D model was presented to the participants, followed by a guided group discussion focussing on the benefits and fallbacks of the technology. Specific topics of discussion were:

- How could this technology benefit your business?
- What kind of benefits would it have?
- Who else could benefit from this technology?
- How might they use it?

- What else can be shown or modified to make the technology more powerful?
- What do other technologies offer that this does not?

5.1.2 - The Lessons Learned

The test case focus group was most successful in achieving its purpose of establishing the issues related to planning and running a focus group. This section addresses the issues which arose regarding recruitment, background information, room set-up, moderating the discussion and general observations and their subsequent influence on the planning of the major focus group research in this thesis.

It is essential to start recruitment early and to ensure people have plenty of warning in regards to dates. Problems confirming exact numbers of participants could be improved with a simple confirmation system. Setting up a website to record this confirmation (ie, ticking a box if they would like to participate) may help this and the group should be over recruited by around 30% to allow for people who do not show up. Receiving written information and feedback in the early stages of the focus group development would be very helpful, rather than discussing it at the focus group. The website should ask people some of the initial questions (such as what they do, what tools they use, what decisions they make) so that the models and tasks can be designed accordingly. The participants should be sent an agenda close to the time of the group, so they are aware of what is expected of them.

Specific information about the participants and their concerns should be established before the focus group, rather than during the opening discussion. The participants arrived having considered a few background questions they were emailed prior to attending; however it would be more beneficial to receive written information relating to their concerns in the early stages of the focus group development. The tools they use and decisions they make are essential background data in order to successfully plan the group around relevant demonstrations, models and tasks. Making sure the model is organised in the early stages of planning is an important issue to address. Problems arose with expired software licenses and a method had to be established for selecting additional data layers, which was a time consuming process. A survey should be used to establish which layers of data should be chosen to best describe task scenarios.

Room set-up established an undesired formality to the test case focus group. The use of a company board room meant that the focus group felt very formal, primarily due to the oversized oval table which set a physical distance between the participants and Moderator. Seating for the major focus group should be placed in an evenly spaced small circle, U-shape or equivalent relative relationship, as this keeps everyone on the same level, rather than having the "leaders" at the head of a long table. Getting started on tasks in small groups of 4-5 people will get people talking and working together. This would be a much more successful way of making sure the participants do not feel too intimidated.

Ensuring the discussion stays focussed and on topic, is very important. The moderator plays an essential role in doing this and must be proactive in making sure the participants are all being heard. The test case focus group required a more detailed briefing for the moderator about the types of questions to ask. More open ended questions should be used to get people to express their thoughts and allow the discussion to flow naturally and successfully. Ensuring that for every main question, there are a number of sub-questions or similar questions will also help keep the discussion going. Some people naturally spoke out more than others. The moderator for the major focus group should try to involve everyone in the discussion by asking people who are talking a lot to keep their answers shorter, or by aiming questions specifically at the quieter contributors.

At times, the discussion slowed down or stopped completely. When this happens it would be beneficial for the moderator to expand on questions by asking "can you give me an example?" If more depth is required about a particular question, the moderator should ask "what else?" as opposed to "anything else?" as this implies more discussion, rather than the ending of a discussion.

When assembling and writing transcripts after the test case focus group, it would have helped greatly to have a voice recorder or dictaphone rather than relying on summarised and often brief observation notes.

Allowing participants to converse amongst themselves with tea and coffee at the beginning of the major focus group would establish a more relaxed environment. Thanking participants for their effort and input should be a simple gesture such as morning/afternoon tea and a take-home information DVD.

A two hour session on a Wednesday starting at 2.00pm was successful as the participants' energy levels and mood were excellent. Any less time would see too little discussion and any more would result in a drop in concentration levels.

5.2 - Main Focus Group Testing Methodology

The testing methodology for the focus group study that compared 2D and 3D information systems was developed to provide a comparative and detailed study involving two widely disparate user-groups. It incorporated the lessons learned from the test case focus group and the quantitative and subjective tools of tests and surveys, as used by Cockburn and McKenzie. The focus group research instrument formed the base from which a three part test was devised to systematically compare participants' assessment of the models and software. In the subsequent 2D/3D focus group participants were informed in the task areas and their tasks consisted of three parts over approximately 2 hours, to allow maximum collection of usable and measurable data.

Main focus group: Tutorials (10 minutes)
After a short introduction, the participants were divided up into two small groups, consisting of an equal number of participants in each, ensuring that at least one person from both of the two user-groups was present in each. One group was allocated the 3D resource to work with and the other the 2D resource (See Table

5.1). They completed a brief but clear introductory tutorial according to the software group (either 2D or 3D) they were assigned to.

Table 5.1: Typical dividing of participants into groups (for six participants)

Participants		Task
Group 1:	User-group A, Participant #1 User-group A, Participant #2 User-group B, Participant #1	2D resource (ArcMap)
Group 2:	User-group A, Participant #3 User-group B, Participant #2 User-group B, Participant #3	3D resource (GeoVirtual)

Main focus group: Part 1 – Task (30 minutes)

During this section, the participants were asked to complete a multi-question decision making Task, based on the typical decisions and processes of the two user-groups. This section aimed to get the participants working together, interrogating the information and thinking about the display of the data assisting them in their decision making.

Main focus group: Part 2 – Questionnaire (10 minutes)

After completing the task, the participants were given a self- administered survey (questionnaire). They were asked about the decisions they came to and how, and their understanding of the information resource. The questionnaire was administered without discussion, in order to collect the participants' thoughts before they were exposed to the opinions of others.

Main focus group: Part 3 – Discussion (60 minutes)

Following the questionnaire, the participants formed a single group and took part in a guided discussion based around 4-5 key questions. The discussion group aimed to allow the participants to share and discuss their thoughts and experience with the others in the group, particularly those who completed the same task with the alternative resource.

By excluding one or more of these research instruments, the research would have struggled to fully gauge the impact of the resources to enhance the users' understanding of information. A questionnaire on its own would have lacked the essential practical experience with the resources, as would a group discussion. While a single task or test would have quantitatively measured the success or otherwise of the resources, it would not have provided any additional feedback or data into the participants' thoughts or experience with them, particularly important for establishing both unpredicted benefits and downfalls. The communication of the resources via means of a visual presentation would lack the participant interaction required to test their ability to query and comprehend data.

This breakdown of the time and activities ensured all of the participants were involved in each section of the focus group and their thoughts expressed both independently and as part of a collective group. The combination of both independent and collective data provided both quantitative and subjective evidence for both the 2D and the 3D resources.

6 - Selecting and Evaluating the User-Groups

One of the underlying assumptions of this research is that having a single digital information model for multiple end-user groups could benefit the other groups by showing them information they would not normally use. Two groups from the urban planning industry were selected so that potential overlaps could be displayed to test this assumption. The two groups selected for participation in the main focus group were property developers and city council urban designers. These two groups were chosen due to their varying professional interests and in order to develop a better picture of whether the productivity and usability benefits can apply to more than one user group. Both groups were significantly different in their requirements for specific types of geographic and building information, so an initial online user survey was developed to gather essential data about these differences, and the typical language and decision processes of the two participating user-groups. The data from this Survey was summarised in order to best facilitate the design of practical tasks within the major focus group. The following section discusses the selection of the participating user-groups and analyses the findings of the initial online user survey.

6.1 - Selecting Two User-Groups

The urban planning industry consists of a broad range of professions concerned with urban information. Previous research had revealed an almost limitless list of user-groups who had an interest in this type of information, including: architects, urban designers and visualisers, acousticians, aerodynamics engineers, daylight analysts, real estate agents, film producers, television companies, tourism companies, travel agents, tourists, environmental planners, community groups, the general public, and so on. Two groups is the minimum number required to satisfy the term “multiple”, and the research could not investigate all of these within the 18 month time-frame. A detailed focus group based testing methodology was employed to provide an in-depth analysis of the impact of 2D/3D for specific individual users within the two user-groups, rather than to represent the user-groups as a whole. The emphasis was on the interaction of the data with informed users as a case study, and therefore the development and application of a robust testing methodology to this single example was adequate to reach suggestive conclusions about the success, or otherwise, of 3D display and thus reinforce the strength of the method. The primary focus of this research is to compare, gather and analyse data about where the benefits of these visual methods lie, reaching both quantitative and subjective conclusions.

The goal was to investigate representative groups within the urban planning industry, and two user-groups were chosen to do this:

- Property Professionals (such as valuers, developers, investors); and
- Local Authorities (City, District or Regional Council)

From these two user-groups, the participants were even further defined as property developers (from the Property Professionals group) and city council urban designers (from the Local Authorities group), to allow the tasks and testing methodology to focus on very specific groups concerned with very specific information requirements.

6.1.1 - Local Authorities: City Council Urban Designers

There are 86 different Councils and Authorities throughout the North and South Islands of New Zealand (Statistics New Zealand, 2005). 12 of these are classed as Regional Council. The remaining 74 territorial authorities are made up of 16 City Councils and 58 District Councils (Department of Internal Affairs, 2006). Because this research focuses on case studies of built-up, urban environments, City Councils and their Urban Design departments have been targeted as the end-users, rather than Regional or District Councils, which are generally concerned with larger areas and the smaller townships within them.

All New Zealand City Councils have an Urban Design or Planning unit, composed of an array of people who are responsible for the development of the City, including producing and revising the City's District Plan. The District Plan is a legal document prepared under the Resource Management Act (1991), describing each City's resource management strategy and how the Council aims to control the effects of using and developing their natural and physical resources, including land, water, air, plants, animals, buildings and services (Auckland City Council, 2007). An employee in Urban Design typically has a background in architecture, landscape architecture, geography, local history, strategic planning or policy development, and is most commonly concerned with analysing the impact of various proposals. In order for a proposal to proceed, developers must apply for resource consent if their proposal does not meet the criteria for a "permitted activity" as per guidelines set out in the local urban District Plan. Urban Designers will then review the application and issue or reject the consent based on its merits.

6.1.2 - Property Professionals: Property Developers

The Property Professionals group encompasses a wide range of people from many different fields, including Developers, Real Estate Agents, Investors, Valuers, Surveyors, Architects, Engineers, and Mortgage Brokers. Due to the huge variety of these fields, property developers were targeted as the end-users. A focus group testing methodology requires a small and targeted group of participants, so narrowing the field down to one specific user-group is necessary in this case.

A typical property developer has a background in project management, construction, marketing, sales, investment and design or architecture, and is most commonly concerned with overseeing the complete development of a property (Career Services, 2006). This can include investigating the initial site or property, defining the scope and design direction of the project, overseeing construction, and leasing and marketing the finished development.

As this research aims to also test for the multiple user-group functionality of a single model to meet the needs of multiple users, potential overlaps in information concerns were investigated through the results of the initial online user survey. Property developers require contact with City Councils, in order to obtain any resource consents for their proposals. These applications must carefully consider the standards, assessment criteria and any guidelines as set out in the District Plan.

It is this link between property developers and city council urban designers that produces an opportunity to test for multiple user-group functionality.

6.2 - Evaluating the Information Concerns of the two User-Groups

In order to ensure the development of an appropriate and focused task for the user-groups involved, an initial online user survey was developed. This allowed a substantial amount of written information and feedback to be collected from potential participants and provided a commonality of language and typical task and data requirements for the two user-groups involved. The benefit of this process was the guidance this feedback allowed in the creation of detailed 2D and 3D task models, which could therefore specifically cater to the needs of both user-groups.

The approach was to contact all of New Zealand's City Councils and a random selection of Property Development firms, to analyse their responses as supporting evidence for the task, rather than to statistically represent the two groups throughout the country. The Survey asked the respondents a series of short-answer questions, to establish: a range of job descriptions; the types of 2D and 3D visual digital information tools (if any) were currently being used by these user-groups; the common decisions made using these tools, or others, as a resource, and; a gauge of interest in further participation, as part of the main focus group.

6.2.1 - Developing a Survey for User-Group Analysis

The first draft of the initial online user survey was reviewed by a Statistician to revise the research design and ensure that the results would be relevant and able to be analysed using quantitative methods, such as word association and counting. This review process involved the slight tweaking of the wording and order of some questions in order to receive the best kinds of response from the participants, which could subsequently be measured or counted. For example, when asking a participant to describe their job and what it involves, analysis of the worded answer can be achieved by counting the number of times certain words occur. Verbs (assessing, applying, reviewing, processing, promoting, preparing, developing) describe typical processes they undertake and key nouns (resource consent, district plan, land use, buildings) identify specific issues or aspects they are concerned with. Questions relating to the use of tools were worded in such a way that they were simple to answer for the participants (with three tick boxes) yet the answers could be combined and extrapolated to graphically represent the overall use of tools to a more detailed level. For example, by combining the Yes/No answers from two questions asking whether the participants used 2D and 3D tools respectively, with the one question asking which they used the most 2D/3D/Both, summaries of the distribution of use could be made for both user-groups, respectively.

The Online Web Survey was set out as follows, to collate supporting evidence for the language of the user-groups and nature of their common decisions and processes:

- What region are you located in or nearest to?
- Please choose the user group you are a part of in the urban planning industry:
- What is your job title?
- Briefly describe your job and what it involves: (approx 1-2 sentences)
- Consider some of the major decisions your job requires you to make. Please describe two of those decisions, and the typical process you would use to make them: (Examples)
- Do you often use 2 dimensional visual digital information tools to assist you in your decision making? If Yes, please list 2 or 3 tools you most often use:
- Do you often use 3 dimensional visual digital information tools to assist you in your decision making? If Yes, please list 2 or 3 tools you most often use:
- If you answered Yes to Questions 5 or 6, please state which type of tools you use the most:

6.2.2 - Analysing the Information Concerns of the User-Groups

The initial online user survey provided essential background data, establishing the nature of the two user groups' language and typical task and data requirements. A total of 24 urban designers and 9 property developers participated in the Survey, from New Zealand's 16 City Councils and 16 Property Development firms. This was an adequate level of response, as a large degree of repetition was found amongst the participants' answers, indicating completeness. Whilst this was not necessarily a statistically relevant average response, the evidence of this consistency satisfied the primary concern of the survey: to analyse the two user-groups and define their information concerns. This, in turn, enabled the creation of a focussed, appropriate and relevant task. Word association, counting and grouping was used to analyse the results, which described participant's jobs, common decisions and processes, and current use of 2D and 3D digital information tools.

Firstly, participant responses to Job Titles were grouped together in common categories and Job Descriptions were summarised using keywords (recurring verbs and nouns).

In the case of city council urban designers, four common categories were used to group together typical Local Authority Job Titles (Table 6.1). Of the 15 participants who described themselves as Planners, 11 specifically referred to 'processing' (verb) of 'resource consents' (noun) in their Job Description. This suggested that a typical city council urban designer was most commonly concerned with the analysis of a proposal in relation to the local District Plan and its subsequent issue or rejection of Resource Consent.

Table 6.1: City Council Urban Designer Job Categories

Category:	Number of Participants:
Planner	15
Architect/Designer	6
Geographer	2
Other	1

In the case of property developers, three common categories were used to group together typical Property Professional Job Titles (Table 6.2). Of the 6 participants who described themselves as Development Managers, 5 specifically referred to 'overseeing' (verb) the 'building' and 'development' (verbs) process, with other common responses including 'pre-development property analysis' and 'postdevelopment marketing and leasing' in their Job Description. This suggested that a typical Property Developer was most commonly concerned with the initial suitability investigation of a potential property, the process of developing and overseeing the project and the subsequent marketing and leasing of the finished development.

Table 6.2: Property Developer Job Categories

Category:	Number of Participants:
Development Manager	6
Project Manager	2
Director	1

Following Job Descriptions, participants were asked to consider and discuss two major decisions they commonly make in their job. They were provided with two text boxes to describe the decision and the typical process they would use to make the decision. The decisions were grouped together in common categories using a numbering system, as it was found that some large decisions were concerned with several issues or categories and should be allocated more than one number.

Four common categories were used to group together typical decisions for Urban Designers. The categories were numbered 1 to 4, and the numbers then assigned to each decision. This method allowed some decisions to fall under more than one category (Table 6.3). Decisions relating to Compliance/Consent and Impact/Effects were the most commonly occurring, with 26 and 27 responses respectively given. Because these two issues are both very evenly represented, further analysis to determine the most common decision and process combination was required. 15 of the decisions described were concerned with both Compliance/Consent and Impact/Effects. This suggests that a typical city council urban designer is most commonly concerned with analysing the impact and effects a proposal might have on the surrounding areas, particularly those issues as set out in the local District Plan, and thus concluding whether to issue or reject a Resource Consent based on that potential impact. Some of the typical responses included: Using plans, elevations and a site visit to assess the visual impact of a new building in a heritage zone; analysing the shading impact of a proposal on surrounding properties during resource consent processing; establishing whether a proposal meets the urban design policies and objectives laid out in the local District Plan and will have minimal environmental impact.

Table 6.3: City Council Urban Designer Decision Categories

Category:	Number of Decisions:
1 = Compliance/Consent	26
2 = Planning/Urban Development Strategy	5
3 = Impact/Effects	27
4 = Design	8

Five common categories were used to group together typical decisions for property developers. The categories were numbered 1 to 5, and the numbers then assigned to each decision (Table 6.4). Decisions relating to Impact/Effects were the most commonly occurring, with 9 responses given. This suggests that a typical Property Developer is most commonly concerned with analysing the impact and effects their development might have on the surrounding environment, particularly those issues as set out in the local District Plan, in order to prepare and submit Resource Consent documents. Some of the typical responses included: superimposing drawings, sketches and renders of the proposed development onto photos of the surrounding landscape as part of a resource consent application, to provide evidence of visual integration; using sun diagrams to illustrate solar shading impacts for neighbouring properties; assessing a physical site against the local District Plan to establish whether it will have a negligible impact and thus be suitable for the proposed development.

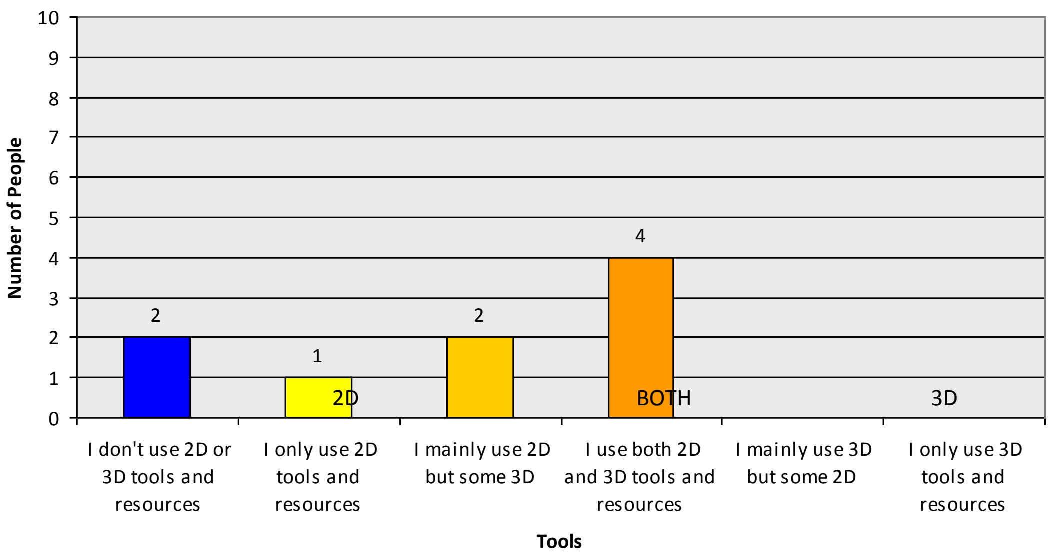
Table 6.4: Property Developer Decision Categories

Category:	Number of Decisions:
1 = Compliance/Consent	5
2 = Impact/Effects	9
3 = Financial Investment Analysis	5
4 = Project Management	3
5 = Other	1

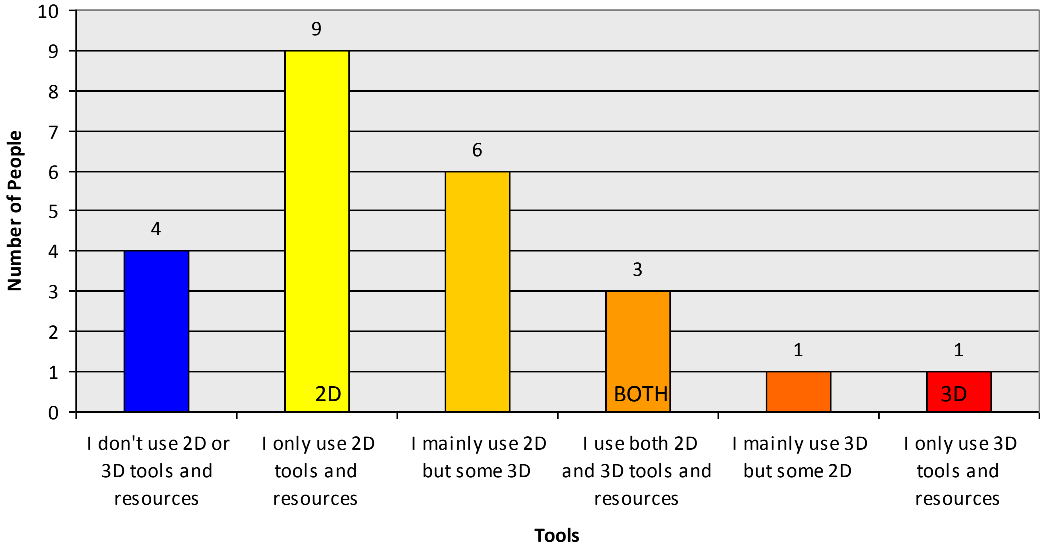
This data guided the choice of task development, ensuring an accurate and representative task was created to satisfy the typical decisions for each respective group, using both a 2D and 3D display method, also allowing overlaps in information requirements to be tested.

Finally, the initial online user survey provided a small snapshot suggesting the current use of visual information tools by the user-groups who participated. A variety of 2D and 3D tools and resources were used by both city council urban designers and property developers. The range of 2D tools included: plans, sections and elevations; surveys, aerial photographs and Land Information New Zealand (LINZ) data; Terralink products, including Terraview, Terranet; Portable Document Format (PDF) files; GIS based software, including ESRI products; and Computer Aided Design (CAD) software, including AutoCAD, Bentley Microstation, Vectorworks. The most commonly used 2D tool was GIS based software, used by 33% of the participants (Graph 6.1). The range of 3D tools included: Physical 3D modelling; Perspective drawings and Adobe Photoshop; 3D based GIS software, including ArcScene and ArcGlobe; CAD software, including Google SketchUp, 3D Studio Max, Bentley Microstation and Key to Virtual Insight (K2Vi); and Google Earth. The most commonly used 3D tool was CAD software, used by 27% of the participants (Graph 6.2).

Graph 6.1: Use of Tools – Property Developers



Graph 6.2: Use of Tools – City Council Urban Designers



The Survey also established whether 2D or 3D methods were the most commonly used by each of the user-groups. The data revealed that more city council urban designers used 3D tools on a regular or preferred basis than property developers. This aspect was important to consider during the analysis of the focus group, as the prior understanding and exposure of the city council urban designers to 3D methods may have had an impact on their ability to successfully navigate and use the 3D tool. This factor of experience bias is discussed later in this thesis. However, the survey also revealed that 2D tools and resources were still the most commonly used methods for both user-groups.

7 - Establishing a Test for the Main Focus Group

The main focus group test centred on the completion of an urban planning task, constructed to test multiple user-group functionality and measure the benefit or otherwise of 3D methods of data visualisation over alternative 2D methods. The following chapter outlines the development of the task, influenced by the findings of the initial online user survey. A post-task questionnaire is used to individually assess the impact the different models had on the users, followed by a guided group discussion.

7.1 - The Task

The goal of the task was to provide a means of quantitatively measuring whether the two user-groups could make more informed and quicker decisions using a 3D resource when compared to an alternative 2D resource. The initial online user survey revealed a number of decisions and processes which could be seen to overlap between the two user-groups. It is within this overlap that the focus group task was developed. This overlap in information concerns for two widely disparate user-groups allowed the research to test whether there is a benefit in each group having the other's information available to them.

Both property developers and city council urban designers were widely concerned with issues laid out in the local District Plan and how a proposed development addresses these issues. This was a key concern for both groups as the Developers are required to provide evidence that their proposed development will have minimal impact and integrate well with the existing environment; and the Urban Designers are required to ensure that the proposed development does in fact meet the District Plan requirements and will not impact the existing environment in an overly negative way. Developers require Resource Consent before a proposal can go ahead and a City Council issues this Consent. Therefore, the task was designed around these overlaps in information concerns.

The task required property developers and city council urban designers to work together on assessing the impact and thus viability of a proposed development. The participants had to take into account the District Plan, incorporating a range of information such as strategic management plans for specific areas, precincts, activities, height controls, site intensity, heritage issues, transportation and viewshafts, to analyse the impact of the proposal and fill out a task sheet with 10 randomly selected issues (Appendix 1&2). The task asked some questions about issues specific to both user-groups, and some overlapping questions to ensure a balance in content. Each group was instructed to answer as many of the 10 financial, aesthetic and development related questions, within the given time frame of 25 minutes using their allocated resource.

Key to the selection of the specific task questions was ensuring that all 10 questions could be interrogated and answered using both the 2D and 3D resource. Incorporating questions which were only possible to answer using the 3D resource would create a significant level of bias towards the benefit of 3D. To avoid this, the questions were developed using both of the resources simultaneously.

The user-groups were divided into two equally sized groups to complete the identical task and were given the exact same information and time constraints; however one group was given a 2D information resource and the other a 3D information resource, providing a fair and comparative test. The 25 minute time constraint was the level of time that a completely inexperienced user should have been able to complete the task within, using either resource. Both the 2D and 3D resources were tested with such people to establish these estimates. Those within the urban planning industry, who are more informed in the task area, should therefore have been able to complete all 10 task questions in less time.

The evidence for one resource allowing more informed or quicker decisions was in the answers to individual questions, in regards to correctness of short answer and detail of long answer questions. It was predicted that the group looking at the 3D information may pick up on typical ideas such as loss of view shafts or decreased hours of sun in winter as a result of the surrounding buildings, quicker or more efficiently than the 2D group.

7.2 - The Questionnaire

The purpose of including a Participant-Administered Survey (questionnaire) in the testing methodology was to collate the individual responses of each of the participants regarding how they felt the tool influenced their understanding and decision making, before they were influenced by the responses of the wider group during the group discussion. The use of the questionnaire helped avoid this influential bias, which could have seen the participants agreeing with one-another in order to give what they believe to be a more widely acceptable or generic response. It was important that the questionnaire was completed anonymously, further increasing the likelihood of the participants being honest in their responses.

Incorporating a questionnaire into the research methodology allowed a subjective analysis of the perceived benefit of 3D. Support or otherwise for either of the resources as expressed by the users, provided complimentary evidence for their success when combined with the results from the task. The questionnaire asked the participants a series of eight ordered questions about their experience with the particular information resource they were assigned and how it may have impacted on their decision making.

7.2.1 - Specific Questions

Question 1 asked the participant which user group within the urban planning industry they were a part of, in order to distinguish the results between property developers and city council urban designers.

Question 2 asked which resource the participant used to complete the task, in order to separate the responses according to their use of either the 2D or 3D software.

Question 3 was important to establish the current level of experience of the participant in regards to their previous use of similar tools to the one they were allocated for the task. Personal experience can often bias the results, as the participant may already be familiar with the tool (or similar tools) or the lack of experience necessary to confidently use the tool, meaning they spend longer learning to navigate or understand the new tool's interface.

Question 4 was worded to establish which of the information datasets the participant used during the task analysis. A list of the fifteen datasets was given with tick-boxes next to each, so that the participant could specify which information they used. This was important to establish if any of the datasets of information were more important or widely used or if any were redundant, and also to test whether the property developers used any of the typical city council urban designer's information, and vice-versa.

Question 5 focused more specifically on how useful the availability of other user-group's datasets of information was to the individual participant. This question was asked using a rating of 1 to 5 as follows:

1 – No, none were useful
2 – Yes, some were slightly useful
3 – Yes, several were useful
4 – Yes, most were useful
5 – Yes, all were very useful

This was important to establish a measurable rating of the usefulness of the datasets and to provide evidence for the multiple user-group functionality of a single model.

Question 6 asked the participant to rate how the resource they used affected the time spent in their decision making. The rating scale of 1 to 5 was set out as follows:

1 – Much slower

2 – Slightly slower

3 – Indifferent

4 – Slightly faster

5 – Much faster

Establishing each participant's personal opinion on whether the tool saved them time or not was further reinforced when compared to the total time their group took to complete the task. This provided a relative conclusion as to whether the tool saved time during decision making.

Question 7 asked the participant to think about spatial awareness and the impact the resource had on their ability to evaluate space and depth within the environment. Another 1 to 5 rating scale was used for this evaluation, with the following options describing the impact of the resource on the participant's spatial awareness:

1 – Negative impact

2 – Slightly negative

3 – Neutral

4 – Slightly positive

5 – Positive impact

This question provided clear and measurable evidence for the enhanced understanding, or not, of either the 2D or 3D tool.

Finally, Question 8 asked the participant to think about the display of each of the fifteen individual datasets, and the impact each dataset had on their spatial awareness. The participant was given a grid of tick boxes and asked to tick one box for each information dataset. The grid was laid out as follows:

Information Dataset:	N/A (I didn't use this dataset)	Negative Impact (It decreased my understanding and spatial awareness)	Neutral (No effect on my spatial awareness)	Positive Impact (It increased my understanding and spatial awareness)
Building photographs / Textures	☐	☐	☐	☐
Terrain / Contours	☐	☐	☐	☐
Aerial photographs	☐	☐	☐	☐
Activities maps	☐	☐	☐	☐
Transport maps	☐	☐	☐	☐
Roads	☐	☐	☐	☐
Property boundaries	☐	☐	☐	☐
Building owner data	☐	☐	☐	☐
Site intensity maps	☐	☐	☐	☐
Precincts	☐	☐	☐	☐
Heritage buildings	☐	☐	☐	☐
Height controls	☐	☐	☐	☐
Financial values	☐	☐	☐	☐
Viewshafts	☐	☐	☐	☐
Addresses	☐	☐	☐	☐

The purpose of asking the impact of each individual dataset on the participant's spatial awareness was to better understand which types of information are communicated more successfully in either 2D or 3D.

7.3 - The Guided Discussion

The guided discussion aimed to build on the questionnaire by provoking extended thought and dialogue about the use of the two resources. The primary aims were to establish further and more detailed evidence for each of the respective resources leading to an increased understanding of information, more informed and/or quicker decisions and the ability of the resources to meet the needs of multiple user-groups. The use of a Discussion stems from the focus group research method, where the purpose is to initiate in-depth dialogue between a small and select group of participants, rather than to collate general responses at a superficial level from many people. This method allowed the observation of a detailed case study, which was necessary in order to progress beyond the initial visual impact of the two tools.

The discussion was moderated around five general topics, which were established to extract as much information as possible from the participants. The discussion points were developed around a series of open-ended questions, the responses of which could be systematically collated and summarised using positive, negative and neutral statements to investigate the overall impact of the 2D and 3D resources.

Discussion Point [1]:

The discussion began by each group being introduced to the other group's resource for the first time. Both the 2D and 3D groups were asked to describe their resource to the other group, particularly focusing on how the information was visually displayed and interacted with. The purpose of this was to make each group aware of the differences in the tools they had been using for the same task.

Discussion Point [2]:

Both the 2D and 3D groups were then asked to discuss their feelings on the overall benefits and drawbacks of the resource. This was an important point of discussion to establish whether one or other of the resources had a significant number of perceived benefits over the other.

Discussion Point [3]:

The third point of discussion was aimed firstly at property developers and then at city council urban designers as user-groups. They were each asked to discuss the usefulness of the resource to them in their field, particularly in regards to the information content. This feedback provided evidence for the multiple user-group functionality. Each user-group was asked to expand on their thoughts by discussing whether the resources needed other information to become more useful, or whether there was any specific information particularly that was particularly useful or redundant.

Discussion Point [4]:

This discussion point was aimed at all of the participants in general, to establish whether resources like the ones they used would assist them and save them time in their decision making. This question specifically aimed to find evidence as to whether the resources allowed user-groups to make quicker decisions compared to their traditional processes and experiences.

Discussion Point [5]:

To conclude the discussion, all of the participants were asked to think about spatial awareness. They were then asked whether the resource they used impacted on their ability to understand the spatiality of the proposed development. The focus of this question was on finding evidence for an increased spatial awareness, which can result in an increased understanding of information.

8 - Main Focus Group Planning

In developing a fair and representative test to compare 2D and 3D resources, a number of issues needed to be considered, including establishing the geographic location for the case study, selecting the comparative software, and building the base 2D and 3D models. The following section addresses these issues and describes how each were analysed in order to avoid creating bias.

8.1 - Selecting the Case Study City

The research design for this case study was such that there was a focused analysis of the usefulness and functionality, or otherwise, of 3D models with individual end-users, rather than to represent the user-groups as a whole. Because of this detailed requirement, one city in New Zealand needed to be selected for the location of the modelling and the participants. The case study nature of the research and the focus on interaction with individual users rather than representative user-groups extends to the origin of the participants. While the selected City was not representative on a national scale, it did provide the essential complex urban setting, containing a range of datasets of information which could be utilised in the task.

Property developers are located throughout most of New Zealand's cities. The country's 16 City Councils represent 16 of the most developed urban centres in the country (Figure 8.1). These centres were used as a base to divide the country up in to possible case study cities. This method allowed all of New Zealand's City Councils to be considered for involvement, as well as urban-based property developers.

Figure 8.1: Location of New Zealand urban centres based on City Councils

The 16 Cities were rated in terms of appropriateness using a scaling tool, which listed the six most important aspects to consider when choosing which cities to use and gave them a 1 to 5 value (1 being very poor, 5 being very good). The higher the score, the more "research friendly" the City. For example, an appropriate City would have a lot of current data available, good contacts within the area, a detailed medium-high density urban centre and be relatively accessible. The aspects selected and used to determine each City's rating are described as follows:

[A] Imagery:

The quality of the imagery is rated in regards to quality and currency. Quality is expressed as a scale value, for example 1:8000 means that every 1m of imagery printed or displayed at 100% resolution represents 8000m (or 8km) of physical terrain. Currency is expressed by the most recent capture of the imagery. The newer the imagery, the more up-to-date it is and the more likely it will show recent developments or changes in the area. The points are distributed as follows (Table 8.1):

Table 8.1: Imagery Ratings

5	2006/07
4	2005/06 and 2004/05
3	2003/04 and 2002/03 and 2001/02
2	2000/01 and 1999/00
1	Older than 1998/99
0	No imagery available

[B] 3D Data:

3D Data is measured by the availability of basic 3D building blocks for the area. For this aspect, most cities either had the 3D data, or did not. The remaining cities had stereo data which could be used to capture buildings; however this is a timely process taking around 2 hours per hectare, which is why these cities were given a very low score. The points are distributed as follows (Table 8.2):

Table 8.2: 3D Data Ratings

5	Yes, available
4	N/A
3	N/A
2	N/A
1	No, but data available to build 3D blocks
0	No, not available

[C] Additional Data:

This aspect considers the availability of additional data in the area, while also taking into account access to people in the area who can collect data, such as points of interest (POI) or take photographs for building textures. The points are distributed as follows (Table 8.3):

Table 8.3: Additional Data Ratings

5	A substantial number of people available in the area and excellent data on record
4	A couple of people available in the area and a moderate amount of data on record
3	Could send people from nearby cities to collect data and an average amount of data on record
2	No one available in nearby areas to collect data and a limited amount of data on record
1	No one available in nearby areas to collect data and little to no data on record

[D] Urban Complexity:

Urban Complexity is a measure of the detail in the urban centres, including development and quantity of high rise buildings and the range of land use such as parks, public, private, tourism, retail, and offices. The points are distributed as follows (Table 8.4):

Table 8.4: Urban Complexity Ratings

5	New Zealand's largest and most complex Cities. Central Business District contains a number of high rise buildings (15-20+ storeys)
4	Large City with substantial growth and development. A medium amount of high rise buildings (5-10+ storeys)
3	Medium density City with a few high rise buildings (5+ storeys)
2	Small City with very few buildings above 4 storeys
1	N/A

[E] Accessibility:

Accessibility measures the distance required for myself and/or supporting staff to travel to the focus groups (ie, distance from Wellington City). Cities in the South Island receive an extra point due to the need to travel across sea from the North Island (by plane or boat). The points are distributed as follows (Table 8.5):

Table 8.5: Accessibility Ratings

5	0 km	-	50 km
4	51 km	-	200 km
3	201 km	-	400 km
2	401 km	-	600 km
1	601 km	-	or more

[F] Participants:

Consideration in regards to already established contacts or relationships between the Councils / property developers, and Terralink / Victoria University. The points are distributed as follows (Table 8.6):

Table 8.6: Participants Ratings

5	Excellent connections already established with many people in these areas
4	Good connections with a fair number people in these areas
3	A few connections with people in these areas
2	Very little connections with anyone in these areas
1	No connections with anyone in these areas
0	Too much prior involvement with the research to participate

The table below shows the individual rating scores for the six scaling aspects and the subsequent total score for each of the 16 urban centres (Table 8.7).

Table 8.7: Scores of New Zealand's 16 urban centres

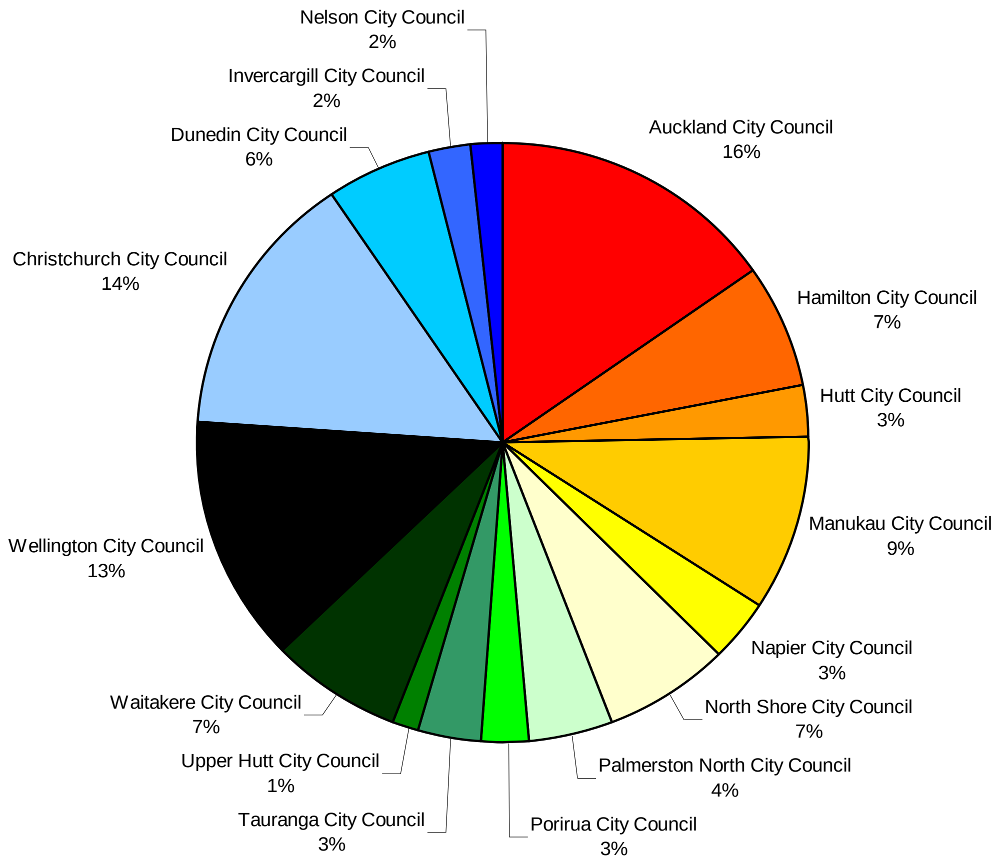
	[A] Imagery			[B] 3D Data	[C] Additional Data	[D] Urban Complexity	[E] Accessibility		[F] Participants	TOTAL
	Quality	Year	Rating	Rating	Rating	Rating	Distance	Rating	Rating	
North Island										
Auckland	1:8000	2005/06	4	5	4	5	493 km	2	2	22
Hamilton	1:8000	2006/07	5	1	4	4	393 km	3	4	21
Hutt City	-	-	0	0	4	3	17 km	5	2	14
Manukau	-	-	0	0	3	3	477 km	2	2	10
Napier	1:8000	2001/02	3	0	2	3	268 km	3	3	14
North Shore	1:8000	2006/07	5	5	4	3	499 km	2	2	21
Palmerston North	-	-	0	0	3	3	126 km	4	4	14
Porirua	1:6000	2004/05	4	1	4	3	19 km	5	3	20
Tauranga	-	-	0	0	2	3	416 km	2	4	11
Upper Hutt	1:8000	2006/07	5	1	4	2	28 km	5	3	20
Waitakere	?	2006/07	5	1	3	3	490 km	2	2	16
Wellington	1:5500	2004/05	4	5	5	5	0 km	5	0	24
South Island										
Christchurch	1:8000	2006/07	5	1	3	5	303 km	2	3	19
Dunedin	1:8000	1999/00	2	1	1	3	617 km	1	2	10
Invercargill	-	-	0	0	1	2	768 km	1	2	6
Nelson	-	-	0	0	1	2	128 km	3	2	8

The top four ranked Cities, as a result of using the scaling method to show the appropriateness of each city in regards to designing the information models and recruiting participants were: Auckland, Hamilton, North Shore and Wellington.

Of these four, Wellington was discarded due to the fact that the Wellington City Council had been involved in the research since its beginnings in 2004. They could not participate due to their prior knowledge of the project, which could have formed biased results. Hamilton was then discarded due to its lack of 3D data. Creating a 3D model is a detailed and fairly time-consuming process. Due to the time limited nature of the research project (18 months), spending extra time creating models was not feasible.

It was therefore proposed that the focus group would be held in Auckland CBD. The central location of Auckland allowed the focus group to be held in a single day and permitted other participants from the wider Auckland region, including North Shore, to take part. The Auckland City Council is New Zealand's largest Council, consisting of 1,666 employees (Department of Internal Affairs, 2006) or 16% of the total people employed by City Councils and representing one of the country's most dense and developed central business districts. Further studies would be required to represent individual users from cities of different urban density in New Zealand as a whole. This would need to include a low-density City, such as Upper Hutt, Nelson or Invercargill, and a medium-density City, such as North Shore, Hamilton, Waitakere or Dunedin, in addition to the high-density of Auckland. The graph below shows the comparative size of the 16 City Councils in New Zealand, based on employee numbers (Graph 8.1). The size of the City Council provides a scale to the size and density of the urban centre.

Graph 8.1: Comparative size of New Zealand's City Councils by number of employees, giving scale of each City's density.



8.2 - Selecting the 2D and 3D Software

Two Geographic Information Systems (GIS) based Software packages were selected for use in the focus groups, one of which has been designed primarily for 2D information display and one for 3D. One could argue that there is no "best" GIS package. A wide variety of both 2D and 3D GIS capable interactive software exist worldwide, each designed to provide different solutions to a diverse and complex range of architectural problems. Due to this issue, there is currently no standard method of evaluation which rates these packages (The GIS Primer, 2007). A range of accessible software packages were researched and reviewed for consideration of use within the task.

In selecting the two packages, the primary issue to consider was ensuring they allowed a fair comparison in the representation of information which was inputted and displayed. The 2D and 3D packages must avoid creating a comparative situation in which the resulting 3D model is guaranteed to look or function better than the 2D model. For example, it is inappropriate to compare a 2D non-interactive GIS tool to a 3D interactive GIS tool, as it may be that the benefit of the latter is the interactivity, not the 2D/3D aspect. Through the research collaboration with TIL, they were able to provide a combination of years of practical experience with the use of GIS software for real-life modelling projects to make recommendations about the type of appropriate software for use during the task. This recommendation was combined with research from independent surveys (where available), popularity, and technological advancement. The two software packages selected were representative of the typical types of software used in the urban planning industry, that is they were both capable of displaying a range of GIS data and were commonly used for urban development and modelling projects.

8.2.1 - 2D Software: ArcMap

ESRI's ArcMap software was selected for this research as it is the most widely used GIS software package throughout the world (GISjobs.com, 1998-2007). GISjobs.com, a website running since 1998 for international GIS professionals, ran an independent survey of 35,526 (as at 11/07/07) into salaries, operating systems, and software packages used. The survey listed 19 of the most common software packages as options and allowed respondents to express how many of these they used in their jobs. 78% of all respondents worldwide use ESRI as one of their packages. The next most commonly used packages include Autodesk (27%), MapInfo (19%), and ERDAS (16%). The statistics also include results for 146 New Zealanders, where ESRI software still dominates being used by 62% of respondents. The next most commonly used packages for New Zealand participants were Intergraph (32%), MapInfo (28%), and Autodesk (17%).

ArcGIS Desktop Edition 9.2 is a software suite released by geographic software developers, ESRI (ESRI ArcGIS, 1995-2007). The suite includes a number of integrated packages including; ArcReader, a viewer for querying maps created using one of the other products; ArcCatalog, a data manager system to file, view, import/export and search for stored geographic information; ArcMap, the central system for creating, developing, querying and exporting maps; and finally ArcScene and ArcGlobe, ESRI's 3D interface which places maps onto a 3D Globe surface for a third dimension of spatial data interrogation.

While ArcGIS offers some 3D options, ArcMap is a comprehensive 2D product, allowing excellent interactivity with a wide range of user imported geographic data. Based on this, ArcMap was chosen as the 2D software package for this research.

8.2.2 - 3D Software: GeoShow

A range of 3D software programmes and viewers were considered for use in the comparative test, including Key 2 Virtual Insight (K2Vi) software, which allows the creation of real-time interactive 3D models from GIS data (K2Vi, 2005); Google Earth PRO version with data import module; and a combination of 3D Studio Max, a 3D modelling and rendering package, and Deep Exploration, a interactive layered viewer for 3D CAD models. TIL, the collaborating business on this research, recommended Spanish software company GeoVirtual's "GeoShow" as the 3D product for use in the task. TIL have over 100 years experience with land mapping and spatial data through their predecessors and have been using GeoShow on client projects with much positive response.

GeoVirtual are a company who specialise in graphic development of multimedia to describe territories and landscapes for businesses and the general public. In 1997, GeoShow was developed as a unique tool which aimed to "enrich the experience of understanding landmass beyond the limitations imposed by paper" (GeoVirtual, 2006). GeoShow essentially allows the import of almost all types of visual and GIS related information, displaying it within a user-friendly, multi-layered interface. Directions Magazine ("The Worldwide Source for Geospatial Technology") has an online Product Buyer's Guide within their website to assist businesses when purchasing or investigating potential tools for their industry. They compare

GeoShow to professional flight simulators in terms of their technical ability to cope with 3D geographic information and state that the final models are of photographic quality with free and fluid movement. Ease of use is also discussed, and Directions state that “the natural navigation interface makes this user friendly technology very simple, even for non professional users” (Directions Media, 2007). Other reasons for selecting GeoShow include its ability to import the same data as ArcMap and provide users with easy interaction and navigation methods.

8.3 - Building the Models

It was essential that the base model for both 2D ArcMap and 3D GeoShow was composed from identical datasets of information, in order to allow a fair comparison of the different ways the exact same data could be visualised. The selection of data was determined by the 10 issues set out in the task. Both models consisted of the same fifteen datasets of information, which were loaded individually into the software. When combined, the individual datasets formed a complete interactive information model. Each of the datasets provided informative visual cues towards the impact of the proposed development analysed in the task, which supported both of the user-groups in their decision making.

The datasets were chosen in three categories: Base data, typical city council urban designer related data, and typical Property Developer related data. In some cases, the initial online user survey revealed clear overlaps between the typical datasets, with several often being used by both of the two user-groups.

The base data for both models began with [1 – Terrain / Contours] which defined the extents of the model and provided a landscape. Layer [2 – Aerial photographs] was added next, to give a sense of photographic location and scale. [3 – Property boundaries] showed the location and size of common buildings, while [4 – Roads] assisted with location. Finally, [5 – Building photographs / Textures] provided a better understanding of the character and appearance of some of Auckland City’s important buildings (Figure 8.2).

City council urban designer related data was overlaid next, which mostly consisted of essential planning maps and information taken from the Auckland Central Area District Plan (Auckland City Council, 2007). The basic [6 – Precincts] map provided a general overview of the different areas the City has been divided into, each with their own policies and objectives. The [7 – Activities map] sets out the regulated activities defined throughout the city. The [8 – Transport map] provides the location and routes of the primary transportation methods, which are regulated to ensure minimal environmental effects arise from their use (Figure 8.3). Restrictions on the type of building and nature of occupation are outlined in the [9 – Site intensity map]. Each building with a heritage value associated with it is defined in the [10 – Heritage buildings] dataset, including its type and location. [11 – Height controls] for building developments are described by a colour-coded overlay map, categorising similar blocks and regions together. The District Plan states that buildings falling within these regions shall not exceed the determined limits, which have been designed for admission of sunlight to public spaces. Finally, [12 – Viewshafts] represent predetermined sightlines, composed of elements the Council has defined as being focal or contextual (Figure 8.4). These viewshafts must not be impeded by the construction of new buildings or structures.

Property developer related data was then overlaid to complete the interactive multilayered models. [13 – Building owner data] taken from Terranet (Terralink International Limited, 2004-2007) reports was allocated to sites and buildings, along with [14 – Addresses]. Finally, [15 – Financial values], including previous sale information and current government valuations, were tagged to individual buildings (Figure 8.5).

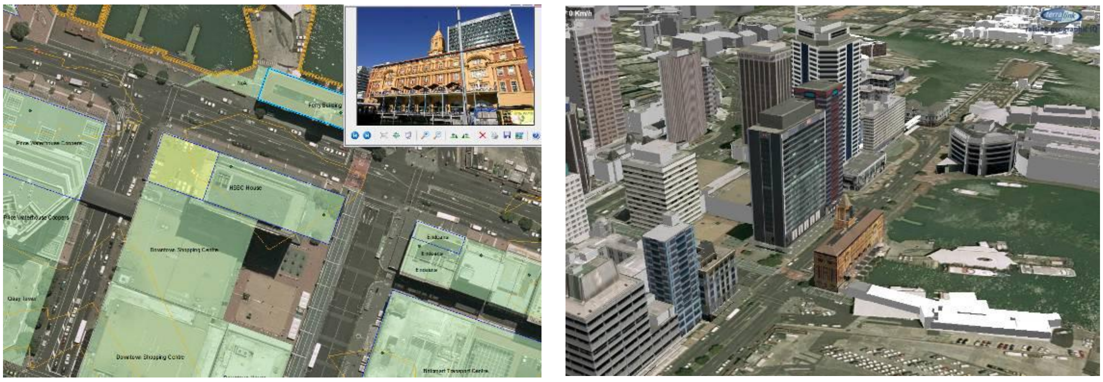


Figure 8.2: (L-R) 2D ArcMap vs 3D GeoShow visualised aerial imagery, contours/terrain, building outlines, texture/photograph data

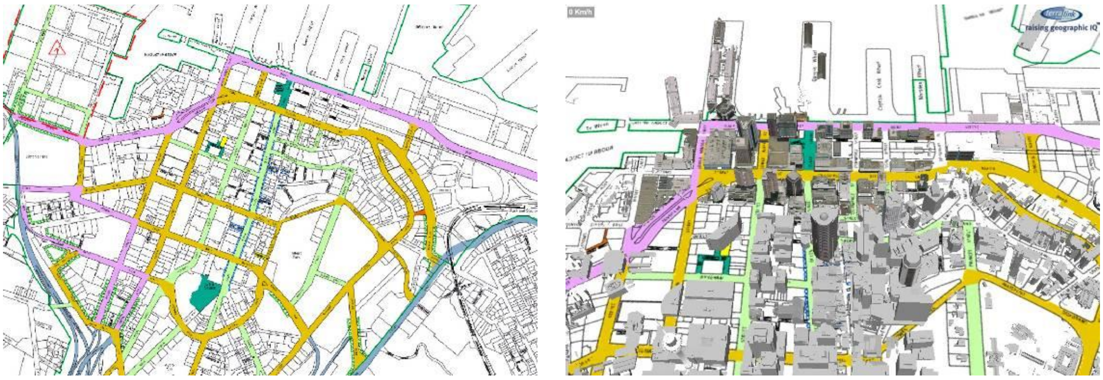


Figure 8.3: (L-R) 2D ArcMap vs 3D GeoShow visualised roading/transport data

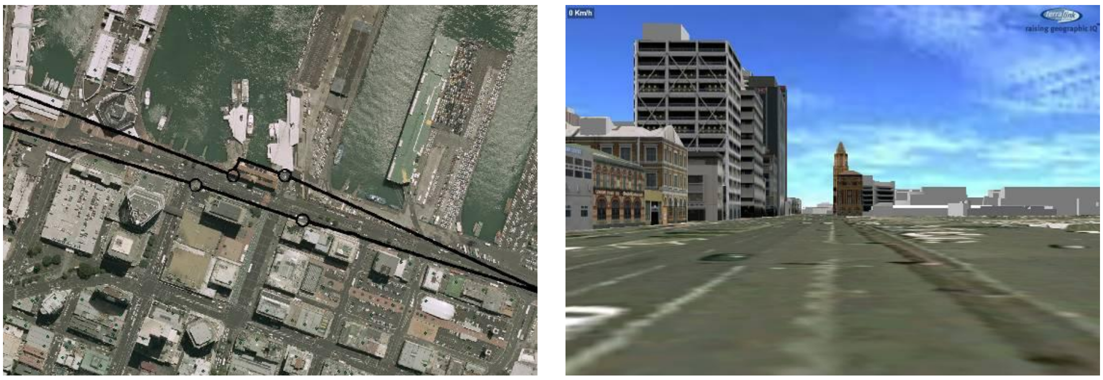


Figure 8.4: (L-R) 2D ArcMap vs 3D GeoShow visualised viewshaft data

Figure 8.5: (L-R) 2D ArcMap vs 3D GeoShow building financial/ownership/address visualised data

9 - Running the Main Focus Group Test

The following section describes the running of the main focus group test and the measures taken to ensure the participants were as unbiased as possible. Issues addressed include levels of concentration of participants, ensuring the participants were relaxed and taking precautions to prevent pre-empted feelings or preferences towards either 2D or 3D.

The focus group session was held at a venue on the edge of Auckland's CBD on a Tuesday morning from 9.45am – 12.00pm. This allowed participation from people both within the CBD and the wider City, with easy parking and access, and was run at a time of day when concentration was high and participants were alert and enthusiastic, as previously discussed in Chapter 5. There were six participants in the focus group: Three property developers and three city council urban designers, which falls in line with the optimum participant numbers of 4-12, as recommended by Greenbaum (1993). This is an appropriate number for this research, which aims to focus on the development of a comparative testing method via a case study to illustrate practical interactions with 2D and 3D models, by individual users within two user-groups. One detailed and comprehensive study is sufficient to enable conclusions to be made about these interactions which in turn suggest where the benefits, if any, may lie.

First and foremost, it was essential to ensure the room was set up to avoid making the participants feel intimidated or formal. A large window at the back of the room provided a pleasant outlook over Auckland City and the tables were set up in a casual U-shape, with seats for technical assistant, Bruce Paterson, and I within the U along with the other participants.

The first fifteen minutes were spent allowing the participants to talk amongst themselves and meet each other, whilst enjoying a cup of tea or coffee, to create a relaxed atmosphere. Participant Information Sheets, explaining the purpose and nature of the research, required input and method of data collection, storage and publication, and Participant Consent Forms were signed at this stage, as part of ethical research requirements.

The focus group opened with a PowerPoint presentation, which was used to inform the participants of what was expected of them during the focus group and how their input would be used in the research. The first slide provided an introduction, which explained who I was and what the research was about without specifically mentioning 2D or 3D. It was important not to mention this aspect of the research until the end discussion, in order to avoid creating personal bias for the participants, particularly if any of the participants had a preference for either 2D or 3D based on past experience. The participants were only informed of the name of the software they would be using and which group they had been randomly allocated to. The next slide explained the reasons for running the initial online user survey and summarised the results for Property Professionals and city council urban designers. Then the task was introduced, ensuring that the participants were aware that the purpose was not to test their abilities or skills, but to focus on the communication of the sets of information in visual ways. They were also informed that the task was not an accurate representation of an actual process, but merely based around common decisions and processes identified during the initial online user survey. Finally, they were reminded that the proposed development was purely hypothetical.

Two laptop computers were loaded up with either 2D ArcMap or 3D GeoShow. The participants were divided into two groups on a random basis however ensuring that there was at least one Property Developer and one city council urban designer in each group. They were assigned to use either 2D ArcMap or the 3D GeoShow. Tables 9.1 and 9.2 show how the participants were assigned.

Table 9.1: Participants using 2D ArcMap

Local Authority: City Council Urban Designer	Property Professional: Developer
2	1

Table 9.2: Participants using 3D GeoShow

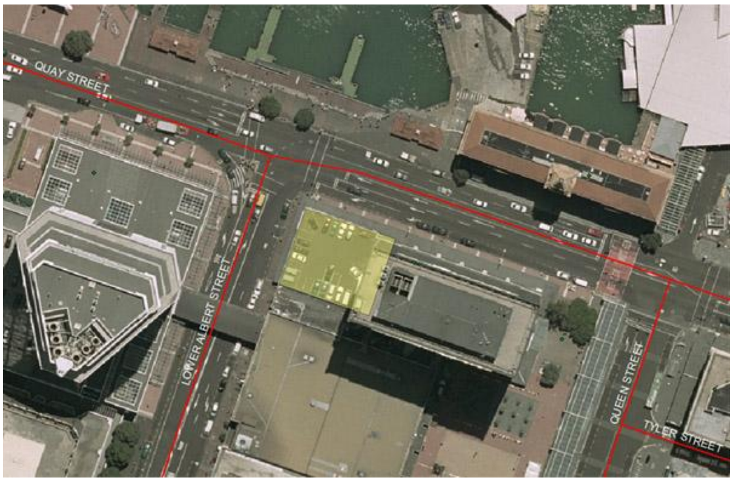
Local Authority: City Council Urban Designer	Property Professional: Developer
1	2

The two groups were instructed to sit on the outside of the U-shaped tables, facing each other, and the two laptops were set up on the inside. This set-up ensured that the two groups could not possibly see what was on the screen of the laptop for the other group, without physically standing up and walking to the other side of the room, which was not allowed.

It is common in practical tests that the initial experience with a new tool or software is spent exploring and learning about the usability and navigation. It was absolutely essential to allow the participants to become familiar with the software they had been allocated, before completing the test (Cockburn and McKenzie, 2001). This was also important in order for both groups, particularly the 3D group, to get past the initial hype and seduction of the new and exciting interactive model placed in front of them and to begin to focus more on the communication of the information contained within it. A tutorial was constructed for both ArcMap and GeoShow, which gave an explanation of the interface, navigation controls and query process for the interactive data. Each group had 10 minutes to progress through the tutorial as a group and learn about the software. The two groups were then given 25 minutes to complete the identical task sheets as a group.

The task required each group to consider the proposed development, which suggested that the owners of the 2-storey HSBC Building on the corner of Quay St and Lower Albert St (Figure 9.1) in Auckland City's Central Business District (CBD) wished to sell the building.

Figure 9.1: Site of Proposed Development (shown in yellow)



This opened the building up to development, where it was proposed that the building would be extended to a similar height to the 20-storey building on the adjoining site, and rented out as office and retail space.

Once the 25 minute period concluded, the participants were asked to hand back their task sheets and were given the individual questionnaires. Completing the questionnaires individually allowed a personal account of the experience with the software, before the participants were influenced by the comments of others in the group discussion.

The group then broke for 15 minutes for a light morning tea in order to refresh their concentration for the group discussion. The group discussion was recorded with a dictaphone in order to assist the transcription process and accurately quote participants anonymously during analysis. Due to the informal and relaxed nature of the discussion, it flowed very naturally and required minimal intervention and moderating. Upon completion of the group, the participants were given interactive information DVD's to take home, containing various models and animations, and a viewer version of the 3D GeoShow software with models of both Wellington and Auckland Cities.

10 - Results

The results of the focus group have been divided into three sections: the task, the questionnaire, and the guided discussion. The combination of these three provides a means of measuring the benefit or otherwise of 3D visual digital information tools via both quantitative and subjective measures.

10.1 - Evaluation of the Task

The results from the 10 question task were analysed in regards to the number of completed questions, the correctness and the level of detail in each group's answers. These three issues provide a quantitative analysis of the ability of 3D to improve the understanding of geographic and building information enabling user-groups to make quicker and more informed decisions.

10.1.1 - Speed

The 2D ArcMap group managed to complete all ten questions within the 25 minute time frame, whilst the 3D GeoShow group only completed eight questions. This suggested that the 2D resource allowed the group to make quicker decisions.

10.1.2 - Accuracy

The 2D ArcMap group also completed all ten of the questions correctly, whilst the 3D GeoShow group completed one of the eight questions they answered, incorrectly. This suggested that the 2D resource also allowed the group to make more accurate decisions, however not necessarily more informed.

10.1.3 - Detail

When it came to analysing the detail of the answers specified by both groups, the 3D GeoShow group had a slight advantage. Particular evidence of this came with the group's responses to Question 4, which asked the groups to discuss the visual and aesthetic integration of the proposal with the surrounding environment. The 2D group stated that the building "will integrate with 20-level building to East and similar height to West subject to specific Harbour Edge sloping control" whilst the 3D group stated the building would have "massive visual impact", "block sea views of buildings behind" and possibly cause a "wind tunnelling effect". This suggests that the 2D group made a rushed and sweeping generalisation, based primarily, if not entirely, on the information given to them in the original task text, which stated that "the existing building should be extended to a similar height to the 20-storey HSBC building on the site to the east". The 3D group listed three factors which clearly stated they had an advantage in the understanding of the scale and impact of the proposed development. This strongly suggests that the 3D resource allowed the group to better visualise and comprehend the proposed development, enabling them to make more informed decisions and statements about its potential impact.

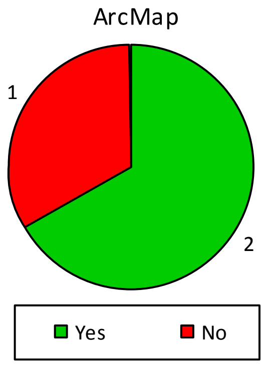
The results from this section of the focus group showed that during a practical task, the 2D ArcMap resource had a clear advantage, with the group completing more of the questions and with greater accuracy, while the 3D GeoShow group provided more detailed answers. This reveals that while 2D methods provide a means of making quicker decisions, 3D methods allow and increased understanding of the information. (See Appendix 1&2 for the full responses from both the 2D and 3D groups.)

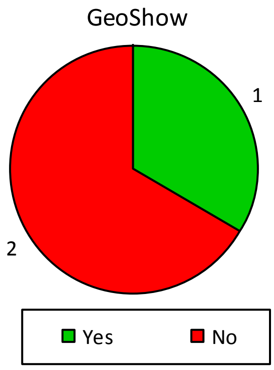
10.2 - Evaluation of the Questionnaire

The questionnaire provided subjective feedback on the participants' personal experience with either the 2D or 3D resource, before they were influenced by the experience of others during the guided discussion. The first two questions were simply used to establish which user-group the participant was in and which resource they were using, to provide a reference for the remaining six questions.

Question 3 revealed that half of the participants had used similar tools to ArcMap and GeoShow before, specifically quoting the use of ArcGIS and Terralink products. Graphs 10.1 and 10.2 show the distribution of experienced participants. This suggested that there could be an advantage in performance for the 2D group, as they have had experience with similar tools in the past. This experience advantage was addressed by allowing both groups to spend time completing the tutorial exercise.

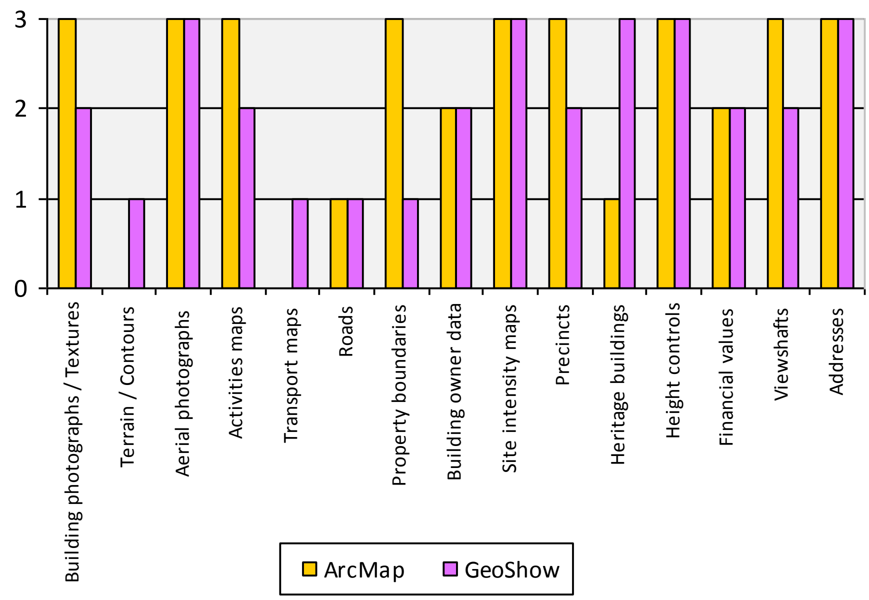
Graphs 10.1 and 10.2: Previous use of similar tools for participants in 2D ArcMap and 3D GeoShow groups





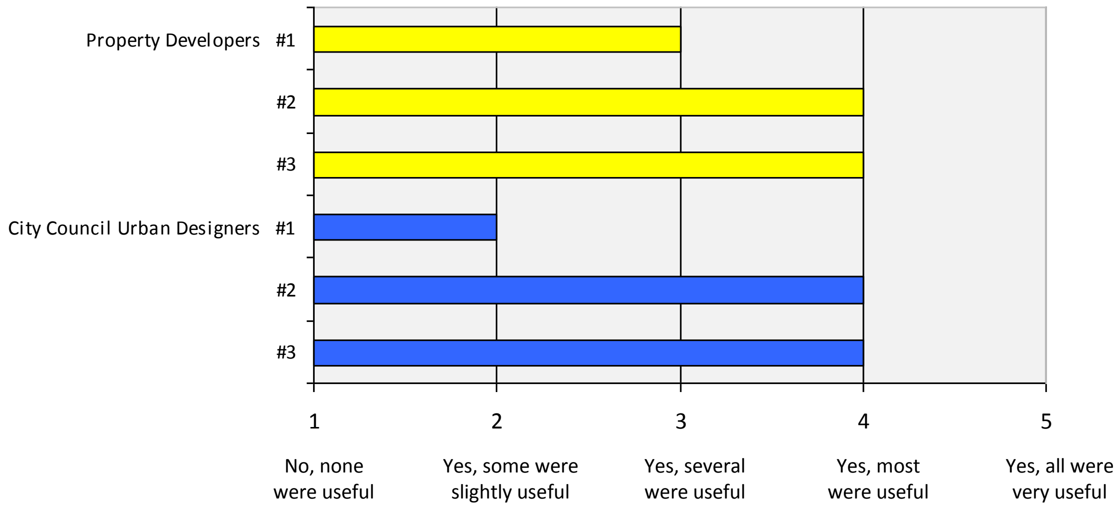
Question 4 established which of the information datasets each participant used during the task analysis, and therefore which were more important or more widely used by each of the groups. Of the fifteen datasets available, the results showed that while all of the information datasets were used by one participant at the least in the 3D GeoShow group, the 2D ArcMap group used fewer datasets (Graph 10.3). The results showed that the datasets used more commonly within the 2D group were Building photographs / Textures, Activities maps, Property Boundaries, Precincts and Viewshafts datasets, while the datasets used more commonly within the 3D group were Terrain / Contours and Transport maps. Aerial Photographs, Roads, Building owner data, Site intensity maps, Height controls, Financial Values and Addresses were used equally by both the 2D ArcMap and 3D GeoShow groups. Overall, this does suggest that most of the datasets contained within the model were used and only two datasets (Terrain / Contours and Transport Maps) may have been redundant.

Graph 10.3: Use of information datasets by participants



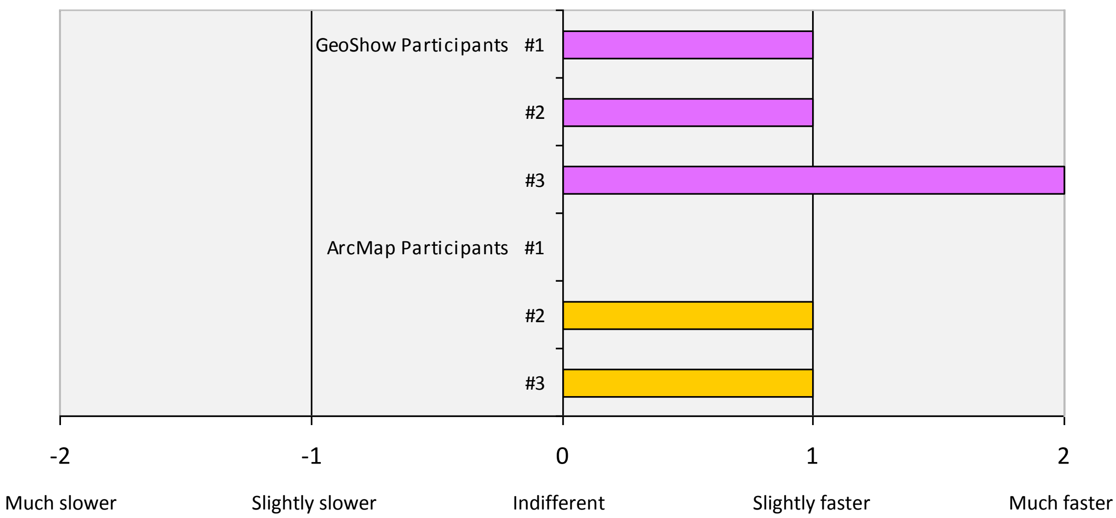
Question 5 then followed on to analyse how useful these additional datasets were to either the property developers or the city council urban designers. Graph 10.4 shows the rating each respondent gave the additional datasets, in terms of usefulness to them. 100% of respondents said that the additional datasets were useful to them to some degree, ie. they were not redundant. The property developers on average found access to the additional datasets marginally more useful than the city council urban designers. This suggests that having city council urban designer information, such as District Planning Maps, is of more benefit to property developers than having their financial and site information data available to city council urban designers. This provides evidence that the resources possesses multiple user-group functionality.

Graph 10.4: Usefulness of information datasets by participants



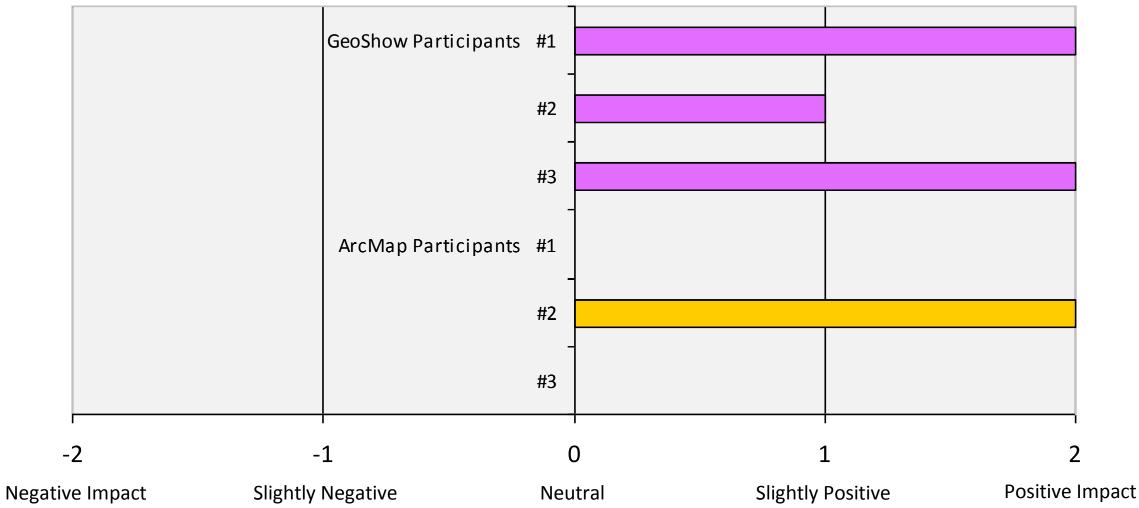
All but one of the participants believed that the use of such a resource would save them time in their decision making (Graph 10.5). This benefit was marginally higher for the 3D GeoShow group.

Graph 10.5: Ability of resource to effect decision making time



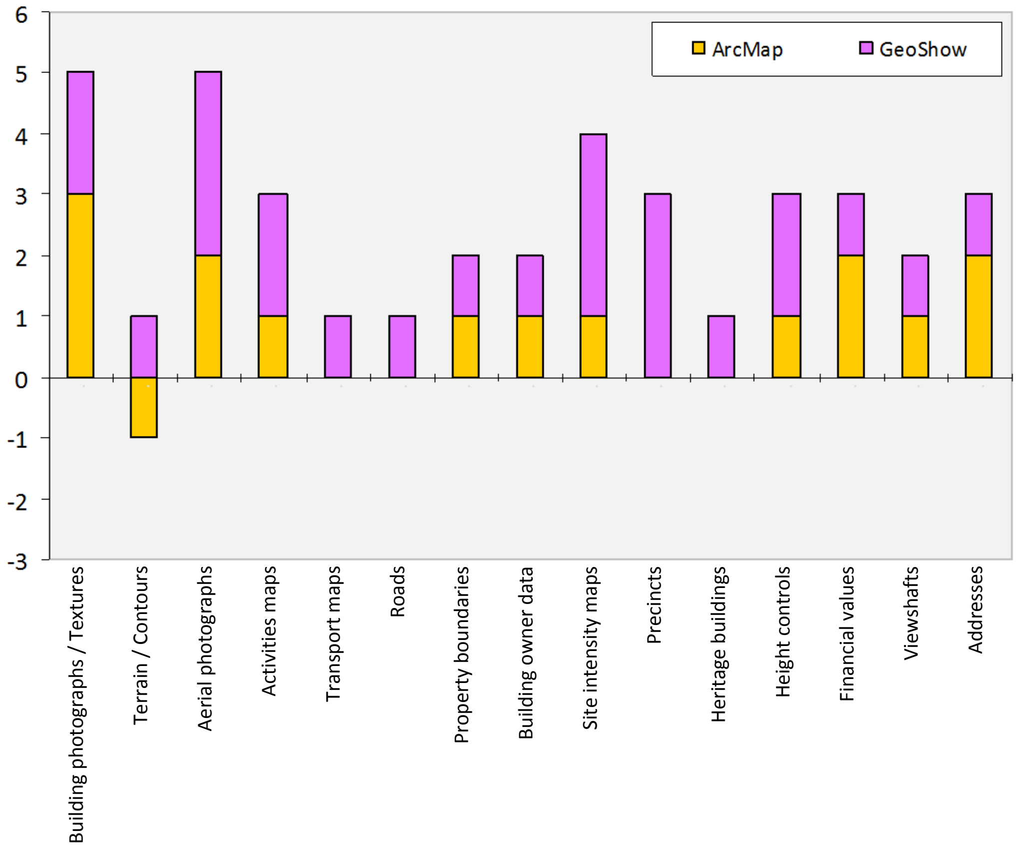
Question 7 focused on the ability of the resources to increase the participants' spatial awareness. The questionnaire revealed that the 3D GeoShow resource had a significant advantage over the 2D ArcMap, with all three participants using 3D stating that it had a level of positive impact on their spatial awareness and general understanding of the proposed development as a whole. Only one of the participants in the 2D group believed that their resource had a positive impact on their spatial awareness and understanding. The results are shown in Graph 10.6. This provides strong evidence for the ability of 3D methods of information visualisation to increase spatial awareness.

Graph 10.6: Impact each resource had on the participants' spatial awareness and general understanding of the proposed development as a whole



Question 8 then followed on to analyse whether the method of information visualisation impacted on the participants' spatial awareness and understanding of each of the specific datasets. By asking each participant to rate whether the display of each information dataset had a negative, neutral or positive impact on their understanding and spatial awareness, evidence for the success or otherwise of the 2D and 3D tools to communicate information was gained. The combined results, illustrated in Graph 10.7, show a significant advantage in the understanding of the datasets for participants in the 3D GeoShow group, with every dataset providing an overall positive impact. Three datasets provided a positive impact for all of the participants in the 3D group: Aerial photographs, Site intensity maps and Precincts; whereas only one dataset provided a positive impact for all of the participants in the 2D group: Building Photographs/Textures. This suggests that there are more types of visual data that are better communicated in 3D, and the nature of the 3D display provided an overall benefit over 2D in regards to understanding of information.

Graph 10.7: Impact the display of each specific dataset had on the participants' spatial awareness and understanding of that information



The most significant evidence showed that 3D had a more positive impact on the participants' spatial awareness than 2D, allowing them to understand both the proposed development as a whole and each individual information dataset better than the 2D group. The participants in the 3D group also rated their resource marginally higher than the 2D group in regards to its ability to save them time in their decision making. Multiple user-group functionality was established by 100% of respondents expressing that the additional information datasets were useful to them to some degree, with a slightly more positive result from the property developers' perspective. This reveals that the 3D group rated their resource higher than the 2D group in regards to spatial awareness, understanding and the predicted ability to save them time in their decision making.

10.3 - Evaluation of the Guided Discussion

The guided discussion allowed additional evidence to be gathered from the participants in a group setting about the use of the two resources. Discussion topics aimed at specific groups (2D/3D or user-groups) were evaluated by grouping responses into categories. The participants' response to each question was analysed by the use of verbs which described either generally positive or negative feedback. Successful aspects of the tools or information were easily identified by the use of more positive verbs and sentences, while unsuccessful aspects were described using more negative terms. The overall results of the guided discussion analysis are summarised in the following section.

After each group introduced the other to their resource, they discussed the benefits and drawbacks. Overall, the 2D ArcMap group listed more drawbacks than benefits. While the benefits focused around the ability of the resource to allow a good general overview of a wide range of District Plan information "as a summary of the District Plan layers, it is extremely useful", the drawbacks were primarily focused around the inability to understand the information about the building proposal "we had no understanding of what the proposal was", the difficulty in navigation "In terms of usability... GIS is quite clunky, awkward and laborious", and the lack of any real advantage of using the resource over their more traditional methods "in terms of going the next step it's got no benefits what-so-ever", "there would still a need to go and look elsewhere".

The 3D GeoShow group listed a significant number of benefits which outweighed the drawbacks. The group stated the primary benefit of 3D was its user-friendliness "it was user friendly", fun interaction "it was good fun", and ability to much better understand the relativity of a proposed development to the surrounding environment "it is of great benefit to be able to see a 3 dimensional picture in front of you, with the surroundings around you", with the only drawback being that it was tricky to get the hang of moving around and basic mistakes often led to errors and back-pedalling, “it is just a matter of inexperience in being able to utilise the software”. This does however show that human-computer interaction and the ability to learn how to navigate a new software does impact on the success or otherwise of the two resources. If this usability aspect is set aside, the feedback shows that the participants believe that the 3D enabled a better understand of the same information.

The resources were then discussed by each user-group separately to determine the perception of how useful they might be to them in their respective fields. While both user-groups were generally positive about the resources, the property developers saw more benefit than the city council urban designers. The property developers found both the 2D and 3D resources to be “very useful, really good” in that they provided a large range of data in one place “all the information is available”, which allowed them to develop an insight into the proposed development faster “it helps get a snapshot a bit quicker”, enabled quick and easy interrogation of District Plan information “being able to interface the District Plan is a great idea, as it is really difficult scrolling through the full copy”, and increased their ability to explain how a proposed development might fit in with the surrounding environment “a big benefit in being able to explain to Council town planners actually, how the building fits in”. The only issue the property developers raised about both of the resources was that the information they contained was already available elsewhere “not necessarily information that isn’t available elsewhere”, however having that information all in one place saved them time.

The city council urban designers generally agreed that while the resources were an excellent starting point for analysing a proposed development, both lacked the ability to make any sort of further more detailed assessments “A useful starting point, but beyond that not particularly useful – you’ve then got a whole host of other assessments that you need to make that this doesn’t have”, which they are required to do in their jobs, “you would still have to rely on a hard copy or more detailed plans”. There was also a concern about the lack of precise detail and the correctness and currency regarding some of the information, “Is it 100% correct? Is it up-to-date? Plan changes come through, things change”. Overall, this feedback suggests that the tools do in fact posses multiple user-group functionality as they stand, however there would need to be more emphasis on specific improvements for the city council urban designers in order for this functionality to be practical and useful. This may also suggest that the city council urban designers had more experience using 3D tools and were therefore suspicious toward the degree of its benefits.

Discussion about the ability of the resources to save time during decision making revealed a slight benefit in using 3D over 2D. The participants using the 2D ArcMap resource all thought it would save a small amount of time in understanding the initial issues over using traditional methods “you would save a little bit of time over the paper copy”, but it would still require going to alternative information sources for more specific information “it’s just more of a back up tool to the hard copy District Plan system”, so this benefit would be small, in retrospect. The 3D GeoShow participants thought the resource would primarily save time by assisting with sales “in sales it could exist” or investigating developments in an offsite manner “would help understanding in different areas... you wouldn’t have to be based there or rely on other architects to inform you”.

The participants stated that by not having to physically visit a site to understand its extents and having the ability to visually understand a development before construction commences “would be helpful from a development perspective of the 3D modelling”, would most likely allow quicker decisions about the development to occur “you could probably make your decisions a lot quicker in that respect”. This evidence supports 3D having an advantage over 2D in regards to saving time during typical decision making processes.

Finally, the ability for the resource to impact on the participants’ understanding and spatial awareness of the proposed development was discussed. This confirmed that 3D methods of information visualisation have a significant advantage over alternative 2D methods. The participants in the 2D group stated that the resource did not help them spatially understand the proposed development at all “didn’t help me in any respect at all”, “there was no real understanding, spatially, of how the project was going to fit in with its immediate neighbourhood”. All of the participants in the 3D group stated that the resource was exceptionally helpful “(it) was a big help”, allowing them to clearly visualise and comprehend the interactions the proposed development had with the neighbouring buildings “being able to see exactly what was going to happen”. One participant said “The 3D was a fantastic system”.

The guided discussion further reinforced the findings from the questionnaire, in that the participants in the 3D group had more confidence and positive feedback to give their resource, than the 2D group. The participants perceived 3D has a number of significant advantages over alternative 2D methods, the most obvious of these being the ability for 3D to enhance the spatial awareness of participants from both user-groups and allow them to have a better understanding of the information within the resource. The participants predicted that 3D would enable them to make slightly quicker decisions than 2D and a basic level of multiple user-group functionality was observed.

11 - Conclusions

The primary focus of this thesis was to find evidence to support the assumption that 3D enables quicker and more informed decision making for user-groups within the urban planning industry, due to its ability to enhance the comprehension of geographic and building information through greater spatial awareness. This research aimed to reach two principal outcomes: To develop a robust testing methodology that allowed a detailed and fair comparative analysis of the benefit, or otherwise, of 3D methods of information interrogation over alternative 2D methods; and to test the ability for a single model to have multiple user-group functionality.

Through the analysis of a number of 2D versus 3D comparative research papers, particularly the work of Cockburn and McKenzie (2001) and Tavanti and Lind (2001), a robust testing methodology was developed to investigate the usefulness of 3D in a detailed and focused manner. The methodology involved individual end-users as participants in a case study, as opposed to representative whole user-groups on a more generalised level, ensuring the participants were able to fully scrutinise the information and not be distracted by its visual representation. The development of this efficient process assisted the study in moving past the initial visual impact of the models and useful observations were possible as a result.

The method employed combined three research instruments to allow a comparative analysis of the effectiveness of 2D and 3D resources to enhance decision making within the urban planning industry. A focus group formed the base from which a task, questionnaire and guided discussion investigated whether a 3D information resource provided a benefit in that it allowed users to develop an enhanced understanding of visual information and enabled them to make quicker and more informed decisions. The task provided quantitative evidence whilst the questionnaire and guided discussion provided supporting subjective evidence for the benefit or otherwise of 3D. Two widely disparate user-groups, whose information interests showed potential overlaps, were selected to further test the functionality of a resource to meet the needs of multiple users: city council urban designers and property developers.

The task development was formulated through extensive user-group analysis by way of an initial online user survey, which established a snapshot of typical decisions and processes of property developers and city council urban designers. The Survey revealed overlaps in information concerns for the two user-groups regarding both preparing and analysing, respectively, Resource Consent applications using the local City District Plan.

Through the analysis of the quantitative task in regards to speed, accuracy and detail of responses and the subjective questionnaire and group discussion in regards to positive, negative and neutral feedback, the research revealed that 3D methods of information visualisation allow users to develop a greater spatial awareness, increasing their understanding of information, when compared to alternative 2D methods. While evidence for this benefit was established using both quantitative and subjective methods, the research indicates that this increased understanding does not necessarily lead to quicker decisions. The ability for a single model to have multiple user-group functionality was confirmed by involving two widely disparate user-groups within the Urban planning industry, where all of the participants who used the resources stated that the availability of the other user-group's information was of a degree of positive benefit to their understanding of a proposed development (Graph 10.4: Usefulness of information datasets by participants)

The final focus group research approach was time consuming with a relatively small, yet extremely detailed case study outcome. By incorporating a three part quantitative and subjective analysis, the methodology collated a substantial amount of measurable and focused data. This same approach could be applied to additional case studies in the future to further explore the detail of additional user-groups or on a larger scale to represent single user-groups as a whole. The methodology proved to be successful due to its robust structure and comprehensive results.

12 - Discussion and Recommendations

When evaluating how to generalise these research conclusions, it is important to address the significance of sample size in this research. The use of a small and specialist group of end-users enabled a focused analysis on usability testing, as opposed to statistically representative results for whole user-groups on a more superficial level. This is important because statistical representation has been shown to be far less important than focused analysis when undertaking usability assessments (Nielsen and Mack, 1994). Analysing usability can be achieved with a relatively small number of participants "three to five evaluators, since one does not gain much additional information by using larger numbers" according to these authors. Their research into heuristic evaluation shows that the quantity of information relative to the number of evaluators increases sharply, until five (or so) evaluators are participating. At this point, the relationship flattens off and there is no major advantage in having a higher number of evaluators. The quantity of information gathered does not significantly increase as the individual evaluators start to pick up on repetitive issues or aspects of usability.

The results of the research reveal both quantitative and subjective analyses of the two resources. The task is an objective method, measuring the benefit or otherwise of 3D by setting practical questions with correct or incorrect answers to be completed within an imposed time limit. Both the questionnaire and guided discussion are subjective methods. The results are the personal opinions of the participants and such opinions are influenced by their experience using the tools. Ultimately, the objective task analysis provides a marginally more measurable and precise conclusion, with less bias from outside influences.

The task revealed that the 2D resource allowed faster and more accurate decisions to be made, even though the 3D resource allowed a greater understanding of more specific information. The questionnaire and guided discussion both revealed the participants in the 3D group firmly believed that their resource had a significant number of advantages in that it allowed increased spatial awareness and subsequent understanding of information, and would therefore allow them to make quicker decisions, while the 2D group were much less confident. This reveals a conflict in results. Even though the 2D resource proved faster and more accurate in a practical timed task, the participants still perceived the 3D resource to have more benefits and that it would allow quicker decisions to be made. It may be that even with the significant amount of time spent completing the tutorial and familiarising themselves with the resource, the "hype and seduction" of 3D still played a part in its positive impact on the participants.

Future development of a process to compare 2D and 3D resources would need to be even more detailed than the focus group methodology employed in this research. While the three-part test was expected to delve past the strong first impression of 3D's visual impact, it appears that this may not be the case. The use of the time constrained task, identical in all aspects for both the 2D and 3D resources, was successful in that it provided an accurate and comparative analysis of the practical benefits. More difficult or detailed or longer answer type questions could reveal more insight as to the level of comprehension of the information.

From a more general perspective, this research has revealed strong evidence for the ability of 3D to communicate some types of information in a more comprehensive way than alternative 2D methods. Software developers and companies who present information to different user-groups should continue to investigate these 3D methods, with a particular focus on usability. A successful 3D resource should communicate information with practical and straightforward methods of navigation and all of the datasets should be clearly labelled and easy to find. There should most definitely be a focus on creating single 3D resources that can cater for multiple user-groups. This is an achievable and practical goal, however a substantial amount of background research into the user-groups the software or resource will be aimed at should always be undertaken first, to avoid including redundant information. Possibly the biggest hurdle is creating a resource that user-groups can trust enough to leave their traditional systems and methods behind, as was evident in the group discussion. This includes issues such as ensuring the resource has up-to-date information, accurate and detailed information, the ability to load additional information, and allow both savings in cost and time to complete their daily tasks. Until 3D can cater to these demands, most user-groups will tend to rely on their 'tried and true' methods.

3D holds huge potential for improving current decision making processes by user-groups within the urban planning industry and this research presents subjective evidence for the perceived benefit by individual end-users. Future research may investigate the links between this perceived benefit and the physically measurable benefit, to establish to what extent the "hype and seduction" of the visual image of 3D plays in masking functionality.

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15 - Appendices

Appendix 1: 2D ArcMap Task Sheet

QE/QS

2D

TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI

VICTORIA UNIVERSITY OF WELLINGTON

Tasks:

- ☐ What precinct does the building fall within? ~~SMAZ~~ SMA2 ✓
- ☐ Will the proposed development impact on any viewshafts? Yes / No
  If Yes, which ones and to what degree?
  No. But very close. Presume viewshaft is o/s boundary ✓
- ☐ Does the site have any heritage significance? Yes / No ✓
  If Yes, briefly describe:
  No.
- ☐ Within your group, discuss the visual and aesthetic integration of the proposal with the surrounding environment.
  Briefly note down the general thoughts: – will integrate with 20 level bldg to east and similar height to west – subject to specific harbour edge sloping control. ✓
- ☐ Which general height control zone does the proposal fall within? No general height Control – Limited by rules. ✓
- ☐ Are there any other issues that may need to be considered in regards to height control?
  QE/QS – Q st harbour edge control zone ✓
- ☐ What is the Basic Floor Area site intensity ratio for the proposal? 6:1 ✓
- ☐ What is the value of the multi-story HSBC building on the same site? $78,000,000 ✓
- ☐ What is located at 12 Queen St? Britomart Trpt Ctr. 146M ✓
- ☐ List the name and value of three other buildings in the area:

Building 1	Name: Mercure Hotel	Value: 23M. ✓
Building 2	Name: Quay tower	Value: 73M ✓
Building 3	Name: PWC Tower	Value: 195M. ✓

Thank you for participating in the Task. Please let the researchers know if you finish the task before the end of the allocated time period, otherwise feel free to continue exploring the data model.

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Appendix 2: 3D ArcMap Task Sheet

3P

TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI
VICTORIA
UNIVERSITY OF WELLINGTON

Tasks:

- ☐ What precinct does the building fall within? Q.E. Q.S / Q.E. ✗
- ☐ Will the proposed development impact on any viewshafts? Yes / No ½
  If Yes, which ones and to what degree?
  No
- ☐ Does the site have any heritage significance? Yes / No ✓
  If Yes, briefly describe:
  No
- ☐ Within your group, discuss the visual and aesthetic integration of the proposal with the surrounding environment. ✓✓✓
  Briefly note down the general thoughts:
  Massive visual impact
  Blocks sea views of buildings behind.
  wind tunnelling effect
- ☐ Which general height control zone does the proposal fall within? Special Height Control ✓
- ☐ Are there any other issues that may need to be considered in regards to height control? ✗
- ☐ What is the Basic Floor Area site intensity ratio for the proposal? 6 : 1 ✓
- ☐ What is the value of the multi-story HSBC building on the same site? $78,000,000 ✓
- ☐ What is located at 12 Queen St? ✗
- ☐ List the name and value of three other buildings in the area:

Building 1	Name: PWC	Value: $195m ✓
Building 2	Name: Quay Tower	Value: $73m ✓
Building 3	Name: Downtown Shopping Centre	Value: $75m ✓

Thank you for participating in the Task. Please let the researchers know if you finish the task before the end of the allocated time period, otherwise feel free to continue exploring the data model.

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