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An Evaluation of 3D Building Modelling and Visualisation packages for Enhancing Public Participation within the Planning Process

Emma Jane Mantle

Declaration

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ABSTRACT

This thesis will look at the importance of 3D Visualization within the planning process and addresses the issue of improving public participation within urban regeneration. The main aim of this research is therefore to discover what type of model the public require in terms of understanding future developments, which may in turn help them engage in the planning process.

In order to achieve the main aim several other aims need to be established, such as; identifying the capacity of the profession in Wales to deliver 3D models of urban environments, evaluating software solutions to create 3D models of urban environments, and to explore emerging techniques that might contribute to the efficiency and economy of producing models of urban environments.

These aims were realised through conducting surveys which targeted the Building Design Profession (BDP) and established which software packages were being used and for what purpose. A second survey was also conducted by means of an exhibition, which aimed to establish what the public require in regards to being presented with proposed developments.

Other aims were realized through conducting trials. These examined the usability of different 3D CAD packages and the possibility of integrating CAD data with GIS, and how it could be used to quicken the modeling process. Results from these trials showed that through the use of workarounds there are possibilities of integrating CAD and GIS data.

The research reported here indicates that members of the public have trouble understanding 2D Plans and Elevations and the data consistently demonstrates that more than 40% of participants chose 3D technology as a more understandable method of being shown future developments.

The results from the two surveys show that although the majority (42.4%) of participants selected 3D technology as their preferred option, only 28% of participating Building Design Professionals in Wales use 3D computer packages, albeit not for presenting propose urban regeneration projects to the public.

From the outset of this research the purpose has been to evaluate whether public participation will be increased if 3D technologies are provided to showcase proposed developments. The more efficient the modelling process, the more feasible and likely it will be that 3D CAD will one day be a paramount tool within the Planning Process. Numerous techniques were included to examine this efficiency.

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Glossary

Animation - A number of static images displayed in sequence to give the impression of movement.

BDP - Building Design Professionals are those industries involved in urban developments. In this thesis, they include Architects, Interior Designers, CAD Technicians', Property Developers, Surveyors and Engineers.

BIM - Building Information Modelling are software packages that can digitally represent a building, including its geometry and the relationships between objects. It stores information about the physical nature of a building and its lifecycle, which can be shared by other users.

Blunders - A term that refers to a mistake or error. In this thesis Blunders mean the errors, big or small, which are present in the LiDAR data.

Collision – A term used to describe the event when one object strikes another. In this thesis it will describe when two or more building elements overlap and cause ambiguities.

DEM - Digital Elevation Models are of the earth's surface.

Desktop Visualisation or Virtual Reality (Non-immersive) - Using the desktop system, the virtual environment is viewed on a monitor. Interaction with the virtual environment can occur by conventional means, such as keyboards.

DSM - Digital Surface Models are topographic model of the surface of the earth that shows vegetation and man-made structures removed from Digital terrain models.

DTM - Digital Terrain Modelling is a computer technique for creating a digital 3D terrain model that can display Plan, Elevation and Cross-section views.

GIS - Geographical Information System is a graphical computer mapping system which records, analyses and broadcasts information of a terrain, including the roads, streams, buildings and soil.

GPS - Global Positioning System involves a number of satellites that transmit microwave signals to GPS receivers to determine location and precise time references.

HMG - Her Majesty's Government (HMG) is the formal term given to a government where authority is vested in the monarch

LOD - Low level of detail relates to a computer package rendering process where the objects hidden from view are left un-rendered until they come into view, therefore reducing the rendering time scale.

LiDAR - An acronym for Light Detection And Ranging, and the technology that determines distance to an object or surface using laser pulses. It measures the elevation of the ground or object and provides Digital Surface Models (DSMs) of the selected area.

Remote Sensing - The method of obtaining information about the Earth from a distance, without being in physical contact with it.

SBM - Single Building Modelling embodies relevant information required during the production period.

TIN - Triangulated Irregular Networks is the connection of points using a series of irregularly shaped triangles.

Visual - Something that relates to the sense of sight.

VBM – A Virtual Building Modelling is a building model created by such Computer software as ArchiCAD, Revit and 3D FloorPlan.

Visualization/Visualisation - The presentation of information not necessarily multi-dimensional but also 2D, such as Graphs.

Virtual Reality (Immersive) - Virtual Reality (VR) is a computer simulation of an actual environment viewed with the use of special gloves, goggles or a full body suit to mimic body movement and immerse the viewer into the 3D environment where they can interact with the environment.

VR/Animation - A term derived to define the animation of a set course within a Virtual environment viewed through a computer monitor or Laptop

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CHAPTER 1: INTRODUCTION

1.1 Focus of this research

"New buildings and spaces are created by architects, developers, planners and many other professionals. But they are made for the people who will use them – the resident, the pupil, the patient, the office worker, the parent in the park. All of our lives are intimately affected by the quality of the environment we inhabit. And, if we genuinely believe we are engaged in creating places for people, we have to put people centre stage" [Sorrell, 2005].

This research strongly identifies with the above statement, which was taken from the Commission for Architecture and the Built Environment (CABE) annual report and accounts for 2004/05. Similar sentiment motivated this doctoral study.

The focal point of this thesis is that the inclusion of public opinion should be normative in regards to planning and urban re-generation processes. At the outset it is recognised that there are a variety of problems associated with the issue of truly representing public opinion: for example defining 'public' or resolving disputes and ambiguities. This thesis is not concerned with these aspects of public policy but is more specifically interested in a technical barrier to inclusion. In the author's opinion, current techniques used to display information about proposed developments are not always easy for members of the public to understand. In this sense, it is difficult for people to engage, and truly participate. Therefore the purpose of this research is to explore the different presentational techniques currently used or available, and to see if a more appropriate and viable solution, suited to communicating designs of future regeneration projects to the general public, might be encouraged.

It is the author's belief that the use of 3D Virtual Environments showcasing future developments will help strengthen viewers understanding of how a development may appear within an existing environment and its effects on the surrounding area once the development is completed. This thesis proceeds on the basis that using an appropriate 3D Virtual model, with its potentialities in visualization, can provide urban designers with a powerful tool to enhance the design process and public participation within it. The benefit of 3D imagery, especially in architecture and urban re-generation, is that it creates one view that does not have to be supported by several 2D views.

One researcher, who shares the same view, is Harvey S Smallman, a Senior Scientist at Pacific Science & Engineering Group (PSE) in San Diego. His research interests are in the mechanisms of human visual perception and how perceptual principles can be applied to information visualization. In 2002 he won the Jerome Ely award for a co-authored paper on the human factors of 3D display use [Smallman, 2004]. Smallman's applied research projects, centres around visualization and display design. He has a particular interest in the visualization principles and in three-dimensional (3D) displays, and suggested that 3D imagery would spare the viewer the "mentally demanding process of scanning back and forth to integrate two planer views"; he goes on to suggest that by "generating many perspectives showing a project from many sides you obtain a much more accurate impression of the size of the project and its architectural relationship with the surrounding cityscapes" [ibid].

This may seem obvious to those who are engaged in 3D modelling processes. But is this what members of the public actually want? Would the use of 3D models actually engage people and encourage them to participate? Or are there residual technophobia or other issues that act as a barrier to the use of these models? This research will aim to detect if 3D visualization and animation is what the public require.

In order to facilitate this research four issues needed to be addressed. The first issue focused on public participation. In November 2002 a White Paper 'New way of urban living' was announced in which the Office of the Deputy Minister [ODPM] envisioned that communities would be involved in "shaping the future of their communities". More recently in the ODPMs Draft Town and Country planning publication [2005], it was suggested that "the public concerned shall be given early and effective opportunities to participate in the environmental decision-making procedures...and shall, for that purpose, be entitled to express comments and opinions when all options are open to the competent authority or authorities before the decision on the request for development consent is taken" [ODPM, 2005].

It is however, the authors' belief that there is a need for improved presentational techniques in order to give the public a real opportunity to participate, predicated on the notion that 3D imagery could strengthen public understanding, and providing more opportunity to tackle the appropriate problem areas known to, and experienced by those living in areas targeted for development. This belief is now being expressed quite widely as the literature review will show, though it was less widely shared at the outset of this project in late 2002. For example, it was recently recommended by Wang[1] [2005], that "The physical nature of planning practice demands that three-dimensional (3D) images should be used to evaluate the effects of planning" [Wang, 2005], rather than "the current techniques of using two-dimensional (2D) maps, with occasional prospective views and static images [ibid].

This is a view shared by other researchers, including Conniff[2] et al [2005] who state that "architects' plans, although accurate to the last millimetre in terms of measurement, rarely give the non-expert viewer a feel for what the space will be like when it is finished".

Further, "It is commonly acknowledged that people often have trouble understanding architects plans, which can lead to discontentment with the end result. As an alternative or additional method of presentation, sketches are often favoured by architects as a method to present ideas in a more fluid style, and are believed to promote feedback and discussion through their appearance" [ibid].
But what is the public view of this? Are the public happy with the current uses of 2D Plans and Elevations or would they, as predicted, prefer to be given sketches or 3D imagery such as an animated walk-past. Strong theoretical arguments have not been supported by empirical study.

So, in order to test this, an experiment was designed where members of the general public were themselves asked to express their own opinions towards different presentational techniques. If it is elitist for professionals to decide the form of developments on the basis of what they think is best, would it not be equally elitist for academics to decide the presentational format that they think

[1] Professor of Planning in the University of Cincinnati. Wang does not come from a 'visualisation' background but took a Ph.D. in City and Regional Planning from the University of Pennsylvania
[2] Dr Anna Conniff is the Principal Investigator on an ESRC-funded project called Understanding Future Environments: Active Exploration versus Passive Observation. At the Scott Sutherland School.

best? In order to talk authoritatively about public participation, it would be necessary to have the public participate in the development of the thesis.

Due to the author's preconceptions that a 3D animation model would be the most favoured technique, it would be necessary to ensure that bias in favour of such an outcome would be eliminated from the study or at least reduced to a minimum. This would become an important consideration in research design. The layout of the exhibition that is described in this thesis reflected a conscious attempt to draw participants away from the 3D animated model, and towards the other techniques displayed. The design and results of this study are central to this research and can be found in Chapter 7 of this thesis.

If 2D approaches are less helpful than 3D approaches, while 2D approaches remain normative, then there may be some obstacles to their adoption. These might include resistance on the part of professionals accustomed to the norm; or there may be technological barriers related to software or data, or a lack of awareness reflected in the lack of demand for new techniques within the planning process itself. To deal with technical and professional barriers, a second issue is to address the capacity and ability of those within the Building Design Profession (BDP) to actually deliver 3D visualisations.

As a result a questionnaire was developed and sent to 350 BDP firms throughout Wales. The survey aimed to find current trends within BDPs, and look at whether 3D technology is being utilized, what software is currently used within BDPs and if not currently producing 3D outcomes, could the software be used to create a realistic 3D model of a proposed development?

This survey gave the author an insight into the current trends within the BDP in regards to computer software and presentational techniques, and provides the foundations for the main study. But if a survey could establish what BDPs were actually doing, this approach could not easily establish what BDPs could be doing if they used available technologies. So a third issue needed to be addressed. It was important for the author to understand how easy, or difficult it would be to produce 3D models. So a review of key software packages from the leading commercial software suppliers, and other packages available on the high street was undertaken to evaluate, and compare their outcomes, and ease of use. In light of this, a further issue arose: the technical and commercial feasibility of using 3D software to provide 3D models for public consultation.

So this fourth issue focuses on whether the use of 3D technology is feasible within BDPs and seeks to establish whether other techniques can be used in conjunction with 3D modelling software, to reduce the time required for obtaining data and creating models.

Section 1.4 describes a research methodology and a programme of work that would address the issues in a coherent and logical manner.

1.2 Context of Study

One of the aims of Her Majesty's Government (HMG) is to improve and protect the environment for those living within it. Therefore several organisations and programmes aiming to deal with the problem of undeveloped communities, and future regeneration have been developed. One programme is the 'New Deal for Communities', which aims to tackle the problem of deprived communities throughout the UK, and improve the main problem areas such as high levels of crime, poor education, health problems, housing and environmental breakdown by allowing local people and communities to play a roll in setting local priorities and determining local action to turn around their neighbourhoods [Dobson et al, 2005]. Other programmes and initiatives involved in urban and neighbourhood regeneration include 'Health Action Zones' and 'Sure Start' developed by HMG aiming to create a better future for children, parents and communities, by providing childcare, improving health, supporting parents and giving financial support where needed [ANON, 2004]. These organisations will be discussed in Chapter 2, section 2.2 and 2.3 of this study.

According to Crocker [2003], "urban regeneration is about Jobs...Investment...and finally it is about wealth", and there is an urgent need to provide "workable solutions to the problems faced by our towns and cities" [Crocker, 2003]. According to Pete Duncan[3], Director of Social Regeneration Consultants (SRC), so many "modern urban areas are faced with a wide range of social, economic, physical and environmental problems" and "physical decay and dereliction,

[3] Pete Duncan specialises in social housing, neighbourhood renewal, urban regeneration and community engagement.

unemployment and poverty" [Duncan et al, 2000] are only a few issues that affect communities, not only throughout the UK, but worldwide.

Each day our communities, towns and cities are evolving, people moving in and out, new styles of living, births and deaths, and these changes, among many others make "the job of predicting future needs of city dwellers and those who depend on the services cities provide, even more problematic" [Aound[4] et al, 2005].

One clear conclusion to be drawn is that communities must be drawn into decision making if the ill effects of 'exclusion' are to be avoided. It seems increasingly clear that paternal, technocratic views of what communities need are often wide of the mark. The democratisation of development appears to be a high priority. HMG express awareness that some community members are reluctant to take part in planning meetings and workshops, therefore they have set up 'Planning Aid' which provides "free, independent and professional advice and support on town planning matters to disadvantaged community groups and individuals" [ODPM, 2004]. 'Planning Aid' will be used to "target communities which traditionally do not get involved in the planning system" [ibid]. A more detailed description of the involvement of community members in regeneration projects can be found in Chapter 2.

Research undertaken since 1994 has put "the role of local communities in neighbourhood-based regeneration programs, firmly in the political and policy spotlight" [Duncan et al, 2000]. The majority of that research was undertaken by the Joseph Roundtree Foundation (JRF), and showed that community involvement with future urban developments is crucial for sustainability.

"Effective public participation in the making of decisions enables the public to express, and the decision-maker to take account of, opinions and concerns which may be relevant to those decisions, thereby increasing the accountability and transparency of the decision-making process and contributing to public awareness" [ODPM, 2005]. "Important issues in which people have a chance to participate, include regeneration programmes, health service provision, anti-poverty work, and local plans for sustainable development" [Church, 2000]. For

[4] Professor Ghassan Aound is Head of School; Director of Salford Centre for Research and Innovation.

the purpose of this thesis, the author will be focusing on public participation within regeneration and planning projects.

"Enabling communities to take on the level of involvement they would like in their neighbourhoods is a significant challenge, and will require not only new resources, but also major and lasting change in the culture and operation of many regeneration agencies" [Duncan et al, 2000]. In the author's opinion, the 'new resources' mentioned by Duncan et al [2000] should undoubtedly include the generation of 3D computer models. "Public participation has been recognised as a desirable element of the planning process, but traditional consultation and communication methods have not always been able to engage a sufficiently broad cross-section of the public to be truly representative" [Appleton et al, 2005].

Another important contextual consideration is the rate of technological advance in the area of visualisation. Developments in the area of computer graphics and virtual reality have now made it possible to replace the 2D image with a 3D image. The production of 3D models can benefit mankind in many ways not only to create awareness of future developments but also as an aid to recreate present and historical scenes and events, to act as medical and surgical aids, for military purposes and vehicle simulation, in-car navigation and city mapping to aid tourist information and so on. According to Fruh[5] [2002] "the necessity for capturing three-dimensional (3D) models of urban environments has been growing steadily during recent years", as television programmes showcasing 3D walks-through have publicised this technology and helped make people more aware of what is on offer.

It is hoped that the outcome of this research will help to enhance public participation by demonstrating which techniques will assist members of the public in their understanding of a proposed development or regeneration project.

1.3 Research Aims and Methodology

Current practice in planning consultations tend to lean towards the use of 2D methods; plans and elevations with the occasional photomontage and perspective views to strengthen the overall realism of a displayed image. It is however the

[5] Fruh [2002] is a researcher at the Video and Image Processing Lab at University of California, Berkeley.

author's view that these current means are deficient in particular ways, and that other 3D methods should be explored.

The main aim of this research is therefore to discover what type of model the public require in terms of understanding future developments, which may in turn help them engage in the planning process.

Having identified the aim of the research, this section now describes the route required to be travelled in order to meet that aim, the methodology to be adopted and the work programme.

Given that most people do not engage in planning processes and given also the lack of awareness of alternative types of models for consultation, it was decided early in the research that any consultative process would need to depart from the 'normal' survey approach using questionnaires or interviews.

In order to truly engage the public it would be necessary to bring them into an environment that simulated a consultation and in which they might then be introduced to the range of alternate techniques available. Originally consideration was given to a complete simulation: that is a virtual planning proposal in a virtual environment. While this would be feasible, it would require a significant feat of imagination and there would be a risk that members of the public would fail to engage.

The better alternative appeared to be to choose a real world development for which there would be a real consultation, but to create a second unofficial consultation that would introduce participants to the range of alternative models or approaches. This approach was also not without risks: would the developers and their agents agree to provide drawings; would members of the public engage in simulated participation in a project; would members of the public be influenced by real biases and preferences related to a real development?

It was decided to adopt the latter approach, given that the risks were probably smaller and appeared to be more manageable. This novel form of survey and exhibition would become the 'main course' in this thesis. The details of it are reported in Chapter 7. The 3D model used in the exhibition is also submitted for examination.

While there would be some satisfaction discovering which technique the public preferred, there would be little point to the exercise if the chosen technique involved 3D visualisation as hypothesised, if the profession could not then deliver such a product, and in an economic way. So the early emphasis would be on surveying professionals and engaging with current technologies. Therefore in order to achieve the main aim some prior questions needed to be answered. So the aims of the research became

- Identifying the capacity of the profession in Wales to deliver 3D models of urban environments.
- Evaluating software solutions to create a 3D model appropriate for a planning consultation
- Exploring emerging techniques that might contribute to the efficiency and economy of modelling processes
- And finally, create a survey targeting the general public and analyse their responses to different presentational techniques.

The following three investigations were regarded as important in producing a rounded piece of research that analysed the situation from several perspectives and could produce reliable, indeed novel, recommendations:

- In order to identify whether Welsh BDPs are able to create 3D imagery and animations in regards to illustrating proposed developments to member of the general public, it was important to discover which 2D and 3D CAD software packages were being utilised by BDPs in Wales and for what purposes. This was achieved by sending a questionnaire to 350 BDPs. This survey is discussed in Chapter 3 of this thesis. Of course in order best to conduct the survey a prior examination of the market in this software had to be conducted to identify the likely products.

  Additionally this survey necessitated a review of questionnaire technique [Fink et al, 1985. McNamara, 1995. Greenfield, 1996. Hopkins, 2000. Fowler, 2002. Patton, 2002. Robson, 2003. Silverman, 2003. List, 2004. Arsham, 2004] and assimilation of descriptive statistics using statistical software.

- In order to identify whether it is economically possible to create 3D imagery and animations with current technology, a selection of some of the leading and lower end 3D software packages was made, which were then tested for their usability in regards to creating models capable of illustrating proposed developments to members of the general public.

  This required the assimilation of the software and the development of a framework, albeit subjective, for evaluating the potential of each package to develop 3D visualisations.

  The thesis provides a short description of this work and example models are also provided as part of this doctoral submission.

- One overhead identified by the author when creating Computer Generated Models was the amount of time required to gather and represent data. This is clearly a potential constraint on the feasibility of using this technology in urban regeneration projects. It soon became apparent that a lack of interoperability between software packages would lead to a requirement to develop 'workarounds': methods of efficiently integrating the outputs of different software products. Therefore allied methods, such as the use of GIS and scanners for quicker data collection, also needed to be examined.

More detailed statements about the methods employed in each of these activities are offered in the relevant chapters (see Section 1.4 for signposting).

These various considerations led to the development of a staged approach to the research represented in the schema in Figure 1.1. Alongside this series of surveys and experiments, the author continued to review a wide variety of books, articles and web sites. In order to monitor this data and store and retrieve it effectively, a table was devised within an Excel document where all information regarding books, Journals and websites are listed. The number of references from each piece of Literature is noted, and a hyperlink added to a word document where reference details and quotes are stored. These Tables can be found in Appendix 1 of this research.

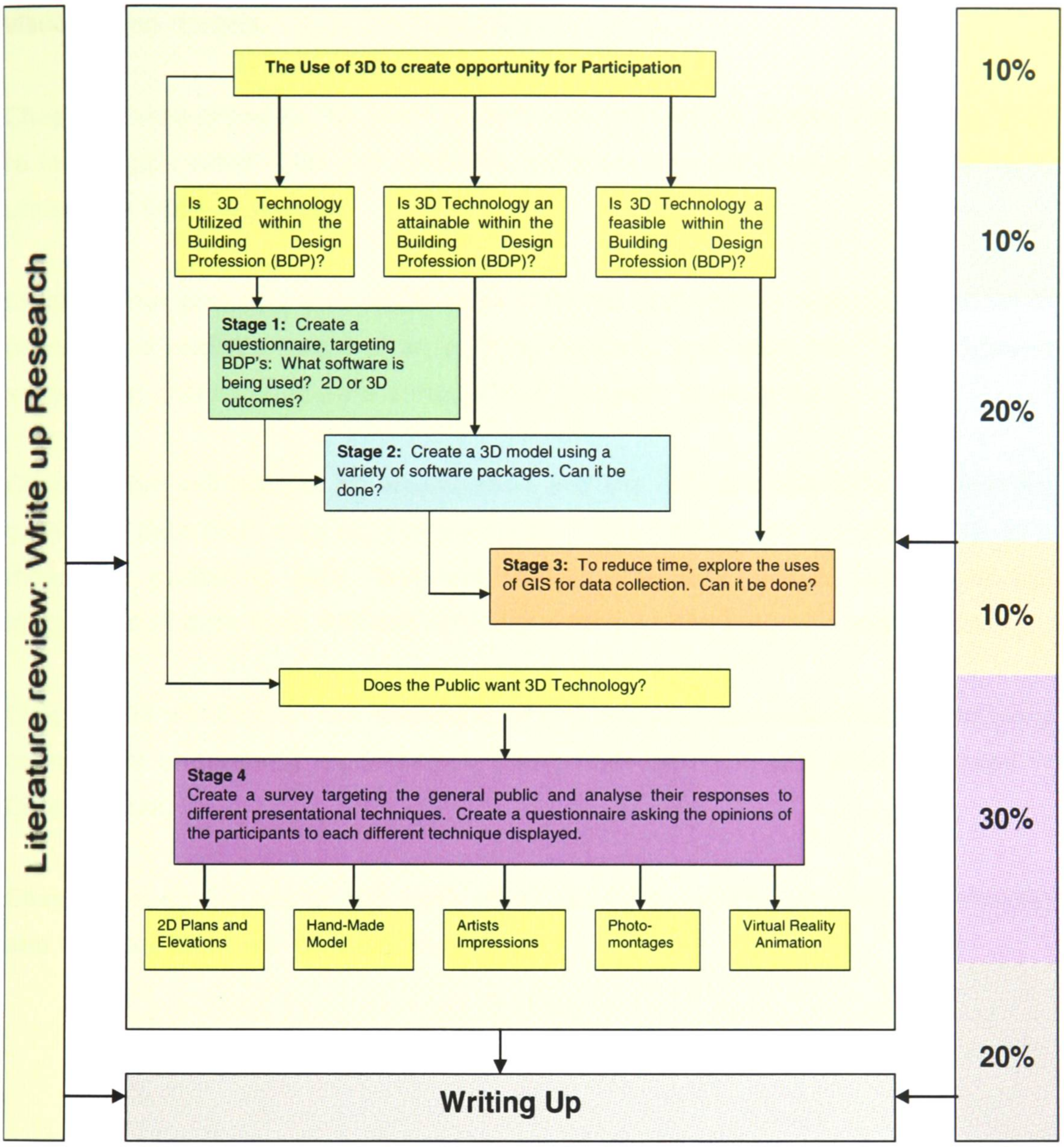

Fig 1.1: Research Structure

1.4 Report Outline

Chapter one has briefly introduced the issues which will be discussed and investigated as part of this study. These include computer modelling techniques for the promotion of public participation in urban regeneration and use for the built environment more generally.

Chapter Two will discuss the issues introduced in Chapter one in more detail, and introduces the extensive literature on two main themes that underlie this thesis:

participation in planning and the development of computer graphics for visualisation models.

Chapter Three presents the findings from a questionnaire survey which was used to investigate which CAD and modelling software applications are currently being utilised by BDPs in Wales.

Chapter Four presents an evaluation of software applications with the intention of producing a realistic model of an existing building, and using the most preferred software in order to generate a model of a proposed development.

Chapter Five will discuss 3D visualization and the different methods available for gathering data from existing environments. This chapter will introduce GIS as a means of gathering data, and will present the summarised findings of the integration of data from GIS software into CAD and BIM software applications.

Chapter Six will discuss the modelling of a proposed urban environment within a community undergoing regeneration, using both CAD and GIS data discussed in Chapter Five.

Chapter Seven focuses on the main study carried out within the local community, and Chapter Eight will conclude this study.

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CHAPTER 2: LITERATURE REVIEW

This chapter reviews two key fields of enquiry that go to the core of the research questions reported here:

- the current state of Public Participation within urban planning and regeneration largely based on documentary analysis and literature review, but supplemented via interviews with planning personnel within Rhondda Cynon Taff (RCT), the local authority that hosts the urban developments later described in this thesis. This part of the review is contained in sections 2.1 to 2.5.
- perceptions of the role of visualisation within this milieu, taken largely from academic sources. This part of the review is contained in sections 2.6 to 2.8.

2.1 Public Participation

'As the world gets more crowded, especially in urban areas, more people are concerned about what happens with their neighbours' property" [Delaney, 2000]. "It is becoming increasingly obvious that until trust, responsibility, and decision making are vested in local people themselves, regeneration programmes will continue to achieve, at best, only partial success" [Duncan et al, 2000].

Tanyer et al [2005] state the obvious in saying that there are several parties included in the creation of a new urban environment, these include; designers, city councils, contractors, city planners and architects". Tanyer et al [2005] however did not mention the importance of public participation, and this reflects a long tradition in which professionals dominate planning processes. The professional easily falls into the trap of believing that the professional knows best - it is after all a matter of training or calling. But modern opinion suggests that in order for a development to be truly successful, the public need to have a more active role in the planning process, which in turn will provide the planners with solutions aimed at solving problems experienced by those living in an area.

Diduck [2007] stated that "there is a need for Public Participation and despite recent improvements, more needs to be done for such efforts to approximate meaningful public participation practice". This statement is supported by Church [2000] who stated that "having a say in matters that affect you and the places where you live and work is simple common sense. It makes sense for local councils, housing agencies, environmental projects to consult with local people - local people know the issues and problems in an area and may well have ideas on how to deal with them" [Church, 2000]. Bulmer [2001] from Victoria University in Manchester would also agree, believing that "greater involvement in the planning process leads to greater understanding and acceptance of plans and proposals. Therefore any process which will improve the relationship between planners and the community they serve, will inevitably result in a more fair and efficient planning system".

Crocker [2003] suggested that "Urban regeneration is a meeting ground where several disciplines can work together". These disciplines however should not only relate to HMG, local authorities and the BDPs involved in the project, but should also include the community members affected by it. "If you want to know how the shoe fits, ask the person who is wearing it, not the one who made it." (Community Planning Handbook: About Community planning) [cited in Matic et al, 2004]. "The affects of any land use change is not only visual, as the quality of life of the local people may be changed in other ways through effects on their environment" [Stock et al, 2005].

There are different reasons why people may want to participate in planning committees, these include the need or desire to know what is happening in their area, how it may affect them, and if it will meet the needs required. Others may want to participate simply at the level of being 'for' or 'against' a development, therefore giving them an opportunity to have their opinions heard, where others may participate in a hope of creating a better area in which to live. For whatever reason, there is a need "for enhanced community involvement in decision making" [Lovett, 2005], to help the community feel a part of future plans, and to gain all the information needed to understand what will be happening in their area. According to Aound et al [2005] "planning is about creating ideas and plans which will inform the future": it should therefore involve the people most directly affected by the decision.

2.2 The Government and Public Participation

All members of the public, regardless of education and status, should "be allowed to take a fuller part in planning decisions that affect their communities and lives, says a leading environmental organisation" [cited in Friends of the Earth, ANON, 2005]. According to Friends of the Earth Cymru, "many individuals and communities feel sidelined by a planning process that can be difficult to understand and to influence. The financial costs of obtaining information, the lack of time to comment, complex procedures, incomprehensible "planner" speak and the negative attitude to objectors are cited as some of the reasons for this" [ANON, 2005]. The author might add the impenetrability of plans and elevations to the untrained eye. The ODPM publication, the 'Statement of community Involvement and Planning Applications' suggested that "Community involvement should not be a reactive, tick-box, process, it should enable the local community to say what sort of place they want to live in at a stage when this can make a difference" [ODPM, 2004].

The objective of the UK planning process is to "regulate the development and use of land in the public interest, however the "worsening conditions of crowding, housing shortages, and insufficient or obsolete infrastructure, as well as increasing urban climatological and ecological problems and the issue of urban security, underline a greater than ever need for effective management and planning of urban regions (O'Meara, 1999)" [cited in Herold et al, 2005]. Although HMG aims to achieve a higher standard of living for all, it is the author's opinion that allowing the general public to participate in the planning process will aid in the development of a more sustainable environment, in addition to achieving a higher quality of life.

In 2000, Duncan et al suggested that HMG regeneration programmes impose their own opinions of how an area should be regenerated, rather than allowing community members to be equal partners in a regeneration project that will affect their own futures, and not that of the designers. Since 2000, there has been much emphasis on Public Participation, however little has changed to help encourage the public to take part within the planning process. Furthermore BDPs dealing with regeneration projects may not have "sympathy to grassroots" as "key decisions are made further away from local councillors" [Caroe, 1995], which highlights the need for community involvement. However, 'public participation' has been a requirement within the planning process for a long time

[Cullingworth et al 2006]. "The planning Act 1968 (and its Scottish equivalent of 1969) made public participation a statutory requirement in the preparation of development plans... By the 1990's government emphasis on the 'consumer' had given way to a 'rediscovery of community...and by 1997 Community Involvement was a "long-standing feature of urban regeneration" [ibid]. So what is going wrong?

According to Kingston [2002], "while there is a statutory requirement for the public to be involved in the planning process this is all too often limited to a fairly basic level of participation. This more often than not allows the public the right to know about what is happening and a right to object, but there is often very little participation in the real decisions".

Concern about real participation is not new and has been growing. For example, in 1995 a report was published by The JRF discussing the problems found on council estates with high rise flats. The report suggested that those affected by any type of regeneration should be "directly involved in helping the council overcome its deficiencies" [Caroe, 1995], giving the community members, the opportunity to identify the real needs and problem to ensure that money is spent in a more efficient way by targeting the social needs of the communities to solve the core problems.

Between 1995 and 2005 HMG has been placing greater emphasis on the need to involve the community in regards to urban regeneration, and as a result community involvement should be a major theme for future programmes, giving the community a greater say in their own futures.

In November 2000 a White Paper was published by the ODPM, titled 'Our towns and cities: the future', and promoted peoples rights to have a say in urban projects and in return, HMG believed that sustainability would be achieved, stating that "Community involvement is vitally important to planning and the achievement of sustainable development" [ODPM, 2004].

Also in the year 2000 "the Local Government Act strengthened the government's agenda for local government to engage local people in meaningful consultation [ibid].

In November 2002 a 'New way of urban living' was announced. In the White Paper it was envisioned, according to the Office of the Deputy Minister (ODPM), that communities would be involved in "shaping the future of their communities". "Other initiatives such as the Single Regeneration Budget (SRB), the New Deal for Communities (NCD) and the National Strategy for Neighbourhood renewal, as a whole" [ODPM, 2004a] also aim to encourage increased community involvement.

In 2003, HMG signalled its support of community involvement in planning, when it pledged almost £4million for planning aid [ANON, 2004]. It was stated that the money was being used to "provide improved levels of service, and use innovative methods to involve local communities in the planning process" [ibid]. HMG are aiming to "establish an effective link between the resourcing of community involvement and emerging proposals for neighborhood management and joined-up action by regeneration agencies. "According to a survey carried out by the Community Development Foundation in 2003, the past ten years has shown a rise in community involvement in regards to urban planning [ANON, 2003].

On the downside, in January 2004 Gordon James produced a report called 'Sustaining Spin', which highlighted a number of instances around Wales where planning permission was granted even though the proposals conflicted with planning policy and faced significant local opposition" [Cited in Friends of the Earth, ANON, 2005a].

While awareness exists that the quality of public participation needs to be enhanced, in the real world, real obstacles sustain old practices and frustrate new developments in what is, in any case, the conflicted situation of development and regeneration.

2.3 Local Governments and Public participation

"The Local Government Act 2000 placed a duty on all local authorities in England and Wales to prepare a community strategy." This aimed to encourage the community to volunteer, and to contribute to the achievement of sustainable development.

According to Sheila Davies, Director of development and regeneration for Rhondda Cynon Taff (RCT) "the involvement process is intended to reduce conflict by encouraging consensus" [Davies, 2006]. Davies described the benefits of public participation in terms of giving the community involved a greater sense of ownership of the area, improving community cohesion and confidence. Public participation can also benefit the council as it would give a greater understanding of the community needs, identify and address concerns, and potentially reduce conflict in the planning process.

In 2002 the Welsh Assembly Government[6] published 'Planning: Delivering for Wales' programme" [Cited in Friends of the Earth: ANON, 2005a] which recognized "the need for greater community involvement". The publication focused on delivering sustainable development and economic regeneration in Wales through public participation. This scheme was implemented in a programme by the WAG called "Communities First" [ANON, 2004] and was set up in March 2000, showing that £83m had been granted to improve existing services and to develop new ones [ibid].

"Local Authorities are required to prepare and maintain an up-to-date information base on all aspects of the social, economic and environmental characteristics of their area" [Development Control, 2006]. It is now required by law for all local councils to prepare a 'Statement of Community Involvement' (SCI) which sets out their vision and their policies on the involvement of community members in the decision making process. According to the ODPMs 'Statement of Community Involvement and Planning Applications' published in 2004, "the aim of the SCI should be to ensure that all sections of public, including local groups and organisations, are actively involved in formulating proposals, and that their views are taken into account in decision making", at a pre-application stage, so that views can be taken into consideration as designs are being drawn.

In November 2004 the Welsh Assembly Government developed, and implemented "an integrated Spatial Plan for Wales" which "reflected" the Assembly's "desire to prepare for the future based on the key principles of social justice, equality and sustainability". The idea for the Wales Spatial Plan was introduced in the year 2000 so to investigate "the interaction of different policies and practice across

[6] During this time the department responsible for environment and planning at the Welsh Assembly Government (WAG) and the Welsh Development Agency (WDA) were two of the main associations responsible for urban regeneration in Wales, though in 2006 they merged to become DEIN, the Department for Enterprise, Innovation and Networks.

regional space". All future Development Plans will need to "have regard to the Wales Spatial Plan" [Spatial Plan, 2004],

Under the Planning and Compulsory Purchase Act 2004, all UK councils, including Rhondda Cynon Taff are "required to prepare a Local Development Plan (LDP) for the County Borough" [Davies, 2006]. The LDP will provide the development strategy and policy framework for the County Borough over a fifteen-year period, from 2006 to 2021. It will be used by the Council to guide and control development. As a part of the LDP process, the Council intend to engage with residents, service users, stakeholders and partners in a meaningful and cost effective way" [Development Control, 2006].

"As a part of the LDP process, the Council intend to engage with residents, service users, stakeholders and partners in a meaningful and cost effective way. The Assembly Government's stated intention in changing the planning system is to make it faster, more responsive to change and to improve community involvement" [Davies, 2006]

According to the Rhondda Cynon Taff web site, www.rhondda-cynon-taf.gov.uk, "The purpose of the planning system is to protect amenity and the environment in the public interest. It is not designed to protect the interests of one person over another".

Prior to the LDP being written, the Delivery agreement was produced in order to "establish the Local Planning Authority's (LPA) early, full, and continuous approach to community engagement and involvement in the preparation of the Local Development Plan (LDP), a total budget of £540k will be required to progress the LDP to adoption within the prescribed timescale" [ibid]

The Delivery Agreement consists of two elements, a Project Management Timetable and a Community Involvement Scheme. According to Davies [2006] the Project Management Timetable details the various stages in the preparation of the LDP and how the process of plan preparation will be project managed, and the CIS sets out the Council's principles, strategy and mechanisms for early and continuous community and stakeholder engagement throughout the LDP process and will provide an understanding in terms of: "The ways in which communities might wish to become involved... range of ideas and techniques to ensure that communities are aided in developing their ideas" [Davies, 2006]

2.4 Encouraging Public Participation

According to Oh et al [2005], from the National Institute of Information and Communications Technology, "The planning stage of a project is very important in determining the fundamental view of the whole project...It is this stage at which decisions are made regarding the course of the plan of the entire project". It should therefore be equally important for members of the general public who are affected by new developments, or live close to new developments, to participate in this early stage. However, it is currently more commonplace for members of the public to be asked their opinions once a design has been drawn up, at which point the views of the public come too late and may not even be considered. However with new technologies being developed and software becoming faster and more reliable, this technique could be easily changed. 3D computer software such as Revit and ArchiCAD could be used to give 'What if?' scenarios where drawings may be changed to reflect public opinions and accommodate public concerns, such as lowering a roof height or adding extra levels etc, and seeing the final design before leaving the planning meeting, reducing the need for further meetings along the planning process.

The ODPM 2005 publication of 'The Draft Town and Country Planning (Environmental Impact Assessment) Consultation Paper' stated that "Effective public participation in the taking of decisions enables the public to express, and the decision-maker to take account of, opinions and concerns which may be relevant to those decisions, thereby increasing the accountability and transparency of the decision-making process and contributing to public awareness of environmental issues and support for the decisions taken" [ODPM, 2005]. It also suggested that planners and council members etc, should ensure that the public are given "early and effective opportunities to participate in the preparation, and modification, or review of the plans or programmes." This report also notes that the public are entitled to "express comments and opinions when all options are open, before any decisions on the plans and programmes are made" [ibid]. It is, therefore important that adequate measures are taken to ensure that efforts are made to allow adequate opportunity for members of the general public to express opinions. The ODPMs Draft Town and Country Planning consultation papers [2005] also stated that "The public concerned shall be given early and effective opportunities to participate in the environmental decision-making procedures... and shall, for that purpose, be entitled to express comments and opinions when all options are open to the competent authority or authorities before the decision on the request for development consent is taken".

According to Barry Cullingworth, Senior Research Fellow in the Department of Land Economy at the University of Cambridge, and Vincent Nadin, Reader in the Centre for Environment and Planning at the University of the West of England, Bristol, the "increased importance attached to the Planning Process, and public involvement in it, lies in the belief that it is effective in reducing the scope for later conflict" [Cullingworth et al, 2006]. If, as argued here, 3D visualisation produces greater clarity for stakeholders, then it lessens conflict too, and opens up the possibility that significant savings can be met as conflict is expensive.

According to the RCT Delivery Agreement, "the council is committed to involving as many people as possible" [Davies, 2006] within the planning process regardless of age, colour, ethnicity, sex, age, marital status, sexual orientation, disability, religion, language or nationality" [ibid]. According to Cullingworth et al [2006], the main function of the Planning Process is to "ensure that the wide variety of interest at stake is considered and that outcomes are in the general publics' interest". Rhondda Cynon Taff's 'Delivery Agreement' stated that "The Council is committed to working in partnership with the community as a whole throughout the plan making process" and to involve a wide range of interested parties and individuals by working with "its existing partners in the community and developing new partnerships where possible." [Davies, 2006].

Most recent planning guidance reflects and even extends this emphasis on participation. For example, the Manual for Streets [DCLG, 2007] talks about "the principles of inclusive design". "Inclusive Design:

- places people at the heart of the design process;
- acknowledges diversity and difference;
- offers choice where a single solution cannot accommodate all users;
- provides for flexibility in use; and
- provides buildings and environments that are convenient and enjoyable to use for everyone" [ibid].

If central and local government are really interested in encouraging public opinion, they should be open to new techniques that support their policy.

2.5 Planning Support for the General Public

According to Yeh et al [2005] "one of the important advancements in urban planning technology over the past ten years is the development of urban planning support systems (PSS), which was first advocated by Harris (1989), and subsequently has been receiving much attention from the academic community and planning professionals". According to the ODPMs 'Community involvement in planning' published in 2004, in order to encourage community involvement, information should be provided in a way that communities can understand at a time where their opinions can be considered [ODPM, 2004]. The 'Consensus on Control' [2004] explained how the involvement of community members through forums aiming to discuss and explore agreements between the community and the developers, "is a highly effective vehicle for meaningful community participation". Although extra time would be needed at the beginning of a project in order to organise forums and collect ideas from the community, this in return could prove to be time well invested, as the design will be focused towards the real needs of the community, and not the needs of the designer, and therefore may possibly reduce the numbers of people who may be opposed to new developments. However it is Cullingworth's [2006] belief that "public participation within the planning process will always be restricted"; the author agrees but theorises that the adoption of 3D technology to showcase developments will provide the public with a more understandable form of presentation, and allow them to have a more active role within the planning process.

In order to give members of the general public the opportunity to participate it has been indicated in RCTs 'Delivery agreement' that "the provision of clear written information in accessible locations, and the opportunity to discuss issues on a face to face basis with Council officers" will be provided in order to encourage people to participate within the planning process. In 2005 the ODPMs Draft Town and Country planning consultation papers [2005] suggested that members of the general public should be informed concerning planning developments "whether by public notices or other appropriate means such as electronic media where available" [ODPM, 2005]. This should include "information regarding proposals for plans or programmes, or for their modification or review, and that relevant information about such proposals is made available to the public including inter alia information about the right to participate in decision-making and about the competent authority to which comments or questions may be submitted" [ibid].

According to Hanzl [2007] "Information technology offers new potentials of citizen participation in urban planning. The essential tasks to achieve with the use of new media are: providing a communication platform which suppresses a barrier of non-professionalism, allowing for distant contacts and enabling participatory process management" [Hanzl, 2007].

In Chapter 1 of this thesis it was suggested that the way to encourage public participation is to incorporate more appropriate presentational techniques, such as 3D Computer Generated Models and animations, to clearly demonstrate the purpose and the appearance of a proposed development. The literature review clearly does not contradict this contention.

Though having read the 'Delivery Agreement' it became apparent that 3D technology has not been considered by RCT as a method of improving public involvement and understanding of future proposals. As a result a telephone interview was undertaken with Mr Gareth Hall the Director of the Department of Environment, Planning and Countryside for Rhondda Cynon Taff; the outcome of the conversation showed that due to the cost of supplying 3D models there were currently no future plans to incorporate 3D Visualization within the Planning Process. According to Mr. Hall, occasionally a Hand Made Model is produced but this, once again, is rare due to accumulating costs. However, in a later discussion with Mr Mark Howland, head of Strategic Town Centre Regeneration, it became more apparent that there is a realisation that 3D Technology will benefit the acceptance of future plans, and as a result discussions are being held at the time of writing to develop 3D models of Pontypridd in a partnership between the University of Glamorgan, RCT and the Welsh Assembly Government. According to Christian Fruh [2001] "Three-dimensional models consisting of the geometry and texture of urban surfaces could aid applications such as urban planning" and if this thesis is correct, it should be an essential element within the planning process to encourage public participation.

While it is difficult not to agree with Gareth Hall that not every planning application requires a 3D model, it is equally difficult to agree that 3D modelling will never be feasible because of cost. Even without establishing actual costs, the principal should be a cost - benefit model. Larger, contested and controversial developments take up huge amounts of public as well as private money. If there is likelihood that time and cost might be saved if 3D models are developed, i.e. benefits exceed costs, there is prima facie case for them.

Of course, different actors in the development process have different objectives. Put crudely, if a developer's principal concern is a target rate of return on an investment and a profit from the construction process, notions of public influence over the shape of the development can be threatening. Such difficulties are not insurmountable if social goals can be legitimately grafted on to the development processes. How to give effect to such democratic and social benefits is beyond the scope of this thesis.

It is believed that 3D computer software and Virtual Reality (VR) can be used to create a model to help increase the understanding of urban and residential planning, geographical and environmental analysis, and increase public awareness of proposed developments. Modelling such a scene can come with high time consumption and requires large scale data handling to generate accuracy and realism. Nevertheless, it is possible, and examples will be discussed throughout this study. One of the objectives will be to determine a scale and cost that might be appropriate for planning procedures.

It was evident from speaking to Gareth Hall that there are no future plans to incorporate 3D technology within R.C.T planning processes. It is therefore of paramount importance that in order to encourage public participation, members of the public need to be given support to gain the skills that are needed in order to fully understand planning proposals so that they can play a more significant role in the development process, whatever the preferred technique.

A survey undertaken by Duncan et al [2000] in the UK in 2000, showed that less than a third of "Initiatives" had involved the local occupants when planning to develop their community, and established that getting the local community involved early can have a significant impact on long-term sustainability. It was also suggested that the reason for this lack of involvement, was shortness of time and expenditure. However, even with appropriate funding, it is still difficult for the community to be involved with new developments unless they are given the opportunity to fully understand the project. In order for a community to have a say in new developments, any plans should be discussed and agreed both by the agencies involved, and the community members.

An example of public participation within regeneration was cited in Laing et al, [2005], where researchers at Robert Gordon University in Aberdeen started a project which they named 'Streetscapes'. This project focused on, and aimed to assist with public participation in regards to urban street design. The project members "hypothesized that the use of computer-generated images, taken from fully constructed three-dimensional models, would improve this situation and produce more meaningful designs where public participation was taken into account" [Laing et al, 2005]. The results from the study encouragingly indicate "that image based choice experiments do generate valid, useful results" [ibid].

Another example of public participation within regeneration is the development in Newcastle City Centre, which focused on every aspect of the City Centre. "This includes the built environment, future development proposals, open space, public facilities, public transport, accessibility, employment, education, retailing and housing" [Kirkey, 2005]. The development aimed to encourage public participation from the onset, and was used within this project for a number of reasons; these included, "to find out the priorities and concerns of City Centre use, to identify major issues facing Newcastle which would form the basis for the Consultation Draft of the City Centre Action Plan, and to form partnerships for the implementation of Actions in the final City Centre Action Plan" [ibid]. The results of the public participation showed that there had only been "a limited amount of feedback", and any feedback gathered, had been via Community Committees" [ibid]. Reasons for the lack of public participation may be related to the types of techniques used to present these plans for development, a lack of advertising, or maybe even the public's lack of interest.

In 2005, three years after this research commenced, an article by Appleton et al [2005] stated that researchers from the School of Environmental Sciences at the University of East Anglia, Norwich, carried out a survey to investigate the different methods of presenting proposed developments to the public. The survey focused on a proposed development along the outskirts of Norwich. "Participants were asked which visualisation techniques (from a list) they had experience of as part of the planning process, and any advantages or disadvantages to those techniques; they were also asked for their opinion on how well the public can translate map data into mental images of a finished development" [Appleton et al, 2005].

The results of the research showed that "the more traditional methods of maps and hand drawings are most familiar, with computer-based technologies being less so; however, 3D scale models are the least well-known" [ibid]. The paper confirmed that planning events throughout the UK are dominated by 2D Plans and Elevations. "On the question of public interpretation of maps, the overwhelming tone of responses was that, in general, the public do struggle to turn 2D maps and plans into 3D mental images. Specific issues included problems orientating themselves, and trouble imagining the wider picture" [ibid].

Other examples have been found outside of the UK where Public Participation remains a subject which needs to be addressed and incouraged within the planning process. These examples include:

"In 1998, planners and designers at the University of Illinois at Chicago joined forces with residents and other stakeholders in Chicago's Pilsen neighborhood to implement a participatory planning process. Three methods of visualization were used in a series of design workshops—a Geographic Information System (GIS), an artist using an electronic sketchboard, and computer photo-manipulation" [Al-Kodmany, 1999]. The results showed that "the GIS used in the first set of workshops provided the participants with a rich source of data and contextual information...The artist helped to unveil critical issues, constraints and opportunities. The drawings, together with the artists' notes, provided a storyboard of the community's conversation." [Al-Kodmany, 1999].

A study carried out by Researchers in Switzerland carried out a study which showed that "promoting direct participation on the local level helps landscapes to develop in a sustainable way" satisfy "the needs of the residence better" and "raises the sense of responsibility of the residence for their living space".

Researcher Frieder Luz of Germany discussed how participation has not played a role in planning and development and as a result the acceptance and implementations of new developments is being hindered. Luz [2000] agrees that there needs to be communications between community members and stakeholders but the methods discussed; workshops, marketing and informing campaigns. 3D technology was not mentioned although it is the authors belief that the use of 3D technology would create a much smoother understanding of future plans and as a result would not hinder future acceptances.

According to Church [2005] "participation processes are often ineffective. They don't give people an adequate opportunity to talk, they don't pay much attention to the ideas that come forward, and they don't seem to change anything. As a result people feel they have given their time and energy for nothing". As previously stated, it is the author's belief that the use of 3D modelling technology could help aid public understanding and therefore encourage more interest and increase participation within the planning process.

To summarise at this point, a statutory obligation to encourage participation is often corrupted in practice. While the causes of this cannot be reduced to the absence of appropriate 3D images, some pioneering work suggests that such imagery may enhance participation in the process.

2.6 Encouraging Public Participation through Computer Technology

People enjoy images of built environments.

"Visualization of cities and urban landscapes has been a theme in western art since biblical times" [Levoy et al, 2004]. Visualizing landscapes, rural or urban, has been an ongoing theme throughout many generations. When man learned to draw, he found inspiration in the environment "within which he is engulfed and seems compelled to capture these images and preserve its beauty" [ibid]. Long before the computer, images were hand drawn; cave paintings from over 20,000 years ago conveyed images of events taking place, and demonstrate a human interest in real-world objects and scenes.

The development of the camera by Joseph Nicephore and Louis Jacques Daquerre between the 1820's and the 1830's allowed users to capture images without the use of paints, and video cameras subsequently made it possible to collect and animate multiple images. The development of these technologies revolutionised the 20th century: this new realism changed the world (and allowed art to rediscover imagination). Today, advances in computer technology allow viewers to be immersed in a 3D environment, whether real or imaginary, thus allowing onlookers to see a fuller picture and heralding another revolution.

"Continued improvements in computer performance, software integration, and the availability of high resolution digital mapping and imagery have combined in recent years to greatly enhance the ability to generate 3D virtual environments" [Lovett, 2005]. The first interactive computer system was developed in the 1960's by Ivan Sutherland from MIT. This software was called 'Sketchpad' and allowed users to draw directly onto the computer screen with the use of a 'light pen' [Whyte, 2002], interact and modify wireframe models. 3D representations were initially "targeted towards robotics and automation e.g. allowing a robot to navigate through an unknown environment. In recent years the focus has shifted to Visualization and Communication" [Pollefeys et al, 2002].

The technology of Computer graphics was developed in the early 1950s, however early computers were not developed for design and artistic purposes, but mainly as military and flight simulators.

During the 1950's and 60's the state of computer graphics were very basic and realism was impossible to achieve due to the lack of technological development. These graphics, however basic, laid the foundations for the visual graphic that we see today (2007). During the 1960s, computer graphics were capable of visualizing objects [Kerlow, 2004], however, the computer was not viewed as a design or graphic aid until the 1980's when computers such as the Apple Mac and Intel-based computers became more widely used by design professionals.

From the early 1990's, computer graphics have become the "fabric of everyday life" [Segnar et al, 1991] and are now commonplace in homes, schools and businesses. "The use of the computer, its popularity and their benefits are moving forward with tremendous speed affecting all industries and professions" [Arif et al, 2001].

During the 1980's computers became more practical and useful for art and design technology. The fall in computer prices during the 1990's made the computer a much more popular device for most areas in industry, "professionals from all visual disciplines accepted computer technology as it became more powerful, more practical, and less expensive."[Kerlow, 2004]

The 1990's concentrated on developing the speed and function of computer hardware. "With the midrange hardware systems being powerful enough for most creative needs, a lot of energy and time was spent in optimizing the software techniques" [ibid]. As the use of 3D software became better known and more widely adopted, users of this software became more demanding.

"The new microcomputer systems greatly contributed to the popularization of computer-generated graphics, mainly in the form of videogames" [ibid]. This may be one of the best ways to chart how computer graphics have developed. The Atari console introduced in 1977[7] and the Commodore 64 relied on 8-bit graphics, less than 100KB of RAM and only a 10MHz speed, allowing a palette of no more than eight colours. By the late 80's this 8-bit games console gave way to 16-bit Sega mega drive system with more than one level and more detailed characteristics replacing the two tone box-like characters of the previous 8-bit computer games. In 2000 the Playstation 2 computer console was developed using a 128-bit processor which allowed for over 2 million polygons to be used per frame, very similar to that used in the making of the film Toy Story five years earlier [ibid]. In 2006, the X-box 360 was introduced, and in March 2007 Playstation released its third version. Before this thesis is complete there will be even greater advancements, which will provide adults and children alike with a much more realistic gaming experience, (such as the first release of Nintendo Wii, an interactive gaming system). According to MacFarlane et al [2005] "many of the three-dimensional rendering techniques now available have come about as spin off's from the sizeable and lucrative computer games market".

With these developments, Andrea Fusiello from the University of Verona, states how "one of the central themes in the field of computer graphics is the generation of images of artificial environments capable to convince the viewer that they are looking into a real scene" [Fusiello, 2003]. In regards to Urban Regeneration, virtual environments can provide "increased understanding of complex data sets and simplify critical decision making" [Schlumberger, 2005].

[7] http://www.atariage.com/2600/archives/consoles.html

Taking these two statements together, the development of computer graphics has made possible the understanding of proposed developments by a much wider audience than the traditional BDPs and their counterparts in planning departments. Building information modelling is a profession in the making. The main purpose of a model is to duplicate an existing or proposed design or object [Tarandi, 2003]. Such models allow the user to view the scene from many different angles, from a birds eye view to an eye-level perspective, such as seen by pedestrians and motorists. According to Aound et al [2005] "Taking effective decisions in urban planning requires more than the presentation of the graphical information. Parties need to assess the quality of the environment from different perspectives".

According to The Landscape Institute, [2003] 3D visualization is "one of the best means of communicating the landscape and visual effects of a development to decision makers and the public." Piekarski[8] et al [2005], agree that visualization is an effective tool for communication, stating that "the key to environmental and landscape planning is the visualization of changes to existing features". However, the idea to use visualization in planning and design is not a new concept, in 1997 Dodge[9] et al [1997] produced an article anticipating the advantages of visualisation as a method to "evaluate changes to the built environment on the computer desktop and over the Internet, offering the potential to enhance the planning and design process; and also help communicate ideas and developments to the public at large" [Dodge et al, 1997].

In 2005, 8 years after Dodge et al [1997] suggestion, the government developed the 'Planning Portal', an internet site which aims to enhance public involvement, recognising that "The web today is probably the most important medium for information dissemination internationally" [Tirapet et al, 2006].

"The current UK Government made a commitment to provide 100% of their services on-line by 2005 through ambitious plans to use Information Communication Technologies (ICTs) to deliver a whole range of services to citizens" [Kingston, 2002]. HMG invested over £4m in this project which is promoted as being "your one stop shop for planning information and services

[8] Course coordinator for Operating Systems and Computer Graphics at the University of South Australia
[9] Martin Dodge is a lecturer in Human Geography in the School of Environment and Development, at the University of Manchester

online" [ANON, 2005]. The web site allows the user to access planning information, planning application forms and development plans, track planning applications and appeals, potentially it can be used to help the individual find out about development near them and to give their view of the plans. However, a poster created by the Planning Portal and the ODPM illustrating the results of a survey carried out in May, 2005 showed that the quality of e-planning services is still very poor in most areas of Wales.

Kingston [2002] has been studying the use of participation in planning decisions through the use of the internet since 1997. "It has been shown that E-participation can have practical benefits for participation and offers a means of wider public involvement in particular planning problems. By informing the public and allowing more in depth feedback it can aid the decision making process and help to inform decision makers of the communities view. It can remove some barriers in participation by providing 24/7 access, and it can foster a non-confrontational environment" [Kingston, 2002]. "The internet provides a different type of accessibility from face to face interaction, in that its use is not constrained to a specific time and place the way a meeting between planners and communities would be" [Sutherland et al, 2003], it is a convenient medium for posting such 3D databases for general access. In architecture and urban planning, for example, "a three-dimensional front-end using the WWW opens new channels for communication and interaction between planners and concerned citizens and clients" [Coors, 2003].

The use of the Internet, and the ability to view plans and models on a computer screen reduces the need for office meetings, which from the author's experience can be laborious, especially when problems remain unsolved. "The Internet also provides a sense of anonymity, not possible in a workshop or meeting, allowing people to comment who might otherwise be reluctant, as well as encouraging more innovative and untraditional proposals without fear of embarrassment" [Sutherland et al, 2003].

However there are some disadvantages to the use of the Internet in the planning process. For example, not everyone has access to these facilities due to expense; another reason is lack of experience with the internet - as using the internet to participate in the planning process "requires a level of computer literacy and familiarity that is not universal, often excluding the poor and elderly"

[ibid]. While most libraries now have access to the internet, allowing visitors to use the facilities, there may be some members of the public, beyond gaining access even at the library. Another problem is lack of understanding, once again this applies particularly to some members of the older generation who did not learn this technology at school and may not have a high enough understanding of how the system works.

Dodge et al [1997] had also suggested that "understanding complex information about urban planning and urban design may be greatly extended if the information is visualized" [Cited in Bhunu et al, 2000]. Unlike the Internet, this area has not been much embraced by the government. Yet a synthesis of Planning Portal and '3D' technologies is an exciting prospect and one that offers incredible potential for extending the boundaries of public participation.

2.7 Visualising Urban Environments

The potential of visualization has been recognised by many researchers. As long ago as 1991 Robert Segner from Texas A & M University and William McManus from University of Oklahoma stated that "among the many promising aspects of computer application coming into use in the near and distant future, there is one which has almost limitless potential-- visualization" [Segner et al, 1991]. Chen[10] [1999] suggested that "realistic images are becoming an essential tool in research" and described visualisation as a way to convey "information directly perceptible to human brains so that detailed spatial relationships are revealed."

The literature that relates this potential of visualisation to applications in the built environment reveals a growing consensus: namely that the built environment is a problem that should be wedded to the emerging solution of visualisation. This consensus identifies difficulties (though some contributors are undoubtedly more prone to hype and dismiss the difficulties too easily) but these are not seen as insurmountable. Some examples of this extensive literature follow, initially providing evidence of the consensus, then flagging up some of the difficulties.

In the article 'Sea of Images', Aliaga et, al [2003] from Princeton University, suggested that "computer simulation of real-world environments is one of the great challenges of computer graphics. Ultimately, computer simulation

[10] In 1991 Waiso Chen worked at the Land Use Science Group, Macaulay Land Use Research Institute, Aberdeen

technologies should let an untrained operator walk through a city or building, with a handheld device, which can provide the realistic visual experience of walking through the environment" [Aliaga et al, 2003]. Part of the focus of this research is to establish whether we have come sufficiently close to "ultimately" make practical progress in the real world.

According to Tarandi[11] [2003] "models have been used for many years for a number of different reasons, their main purpose being to duplicate an existing or proposed design or object". "There are many applications requiring such models, both civil and military. Applications relying on 3D-visualization, e.g. visual simulation, virtual tourism, etc. are perhaps the most common ones but there are many other important applications such as urban and environment management, crisis management, spatial decision support systems, command and control, mission planning, etc" [Soderman et al, 2003].

Virtual models can "include 3D building models, transportation network models, and vegetation models" [Dollner et al, 2005]. According to Einemann et al [2004] "the design of digital environments can carry out major social and economic advancements" [Einemann et al, 2004]. MacFarlane[12] et al [2005], would agree with Einemann's suggestion that "landscape visualisation using three-dimensional modelling and virtual reality techniques has emerged as a significant element of research into the environmental impacts of both location specific developments (e.g. a new windfarm) and more widespread environmental change (e.g. climate change)" [MacFarlane et al, 2005].

"The common understanding is that the most important 3D real objects in urban areas are buildings and terrain" (Grün & Dan, 1997; Leberl & Gruber, 1996 and Tempfli, 1998) [Fuchs (1996) cited in Billen et al, 2003]. "Buildings are major visual objects" [Dollner et al, 2005] of any urban model, and according to Zhou et al [2004] "the most important spatial objects in urban areas. One of the main reasons realistic representations of existing buildings are a necessity within a 3D model is that they act as a landmark, giving the viewer a clearer sense of location and a clearer view of how a new development will look within its actual environment.

[11] Dr. Väino Tarandi is a senior consultant in product modelling in Stockholm, Sweden, Technical co-ordinator of Nordic IAI chapter.
[12] MacFarlane is from the Centre for Environmental and Spatial Analysis at Northumbria University.

Jepson[13] et al [2002] believes that 3D visualisation and animation is "extremely valuable at placing new developments into the existing built environment so that it can be evaluated in its actual urban context."

"In recent years, the use of computer-based models of land use change and urban growth has greatly increased, and they have the potential to become important tools in support of urban planning and management" [Herold et al, 2005].

Urban 3D Computer Generated Models have numerous uses, not only are they an ideal method of presenting proposed developments but, as discussed by Coors [2003], 3D imagery can be used, and made available to "investors, urban managers, real estate agents, and tourists". In regards to planning, the use of visualisation throughout the design process would aid to enhance public understand, including clienteles, and the numerous BDPs. "Part of the role of visualization for the public is to provide an opportunity for greater involvement in community decision making" [Bishop et al, 2005].

In regards to urban development "It is probably not controversial to state that planning, participation and the decision-making process all need to be based on, among other things, accurate and realistic visualization" [Benson, 2005]. Miller et al, [2005] believe that visualization "increases the effectiveness of decision making and potentially avoid the costly process of public enquiries". According to Lovett [2005] "there have been applications of such visualisations in both urban and rural contexts, with a particular emphasis on the communication of design", and therefore giving the public an opportunity to understand and contribute towards future developments.

In relation to these difficulties, in 1999 Brooke, from the University of North Carolina at Chapel Hill, commented that "it is tedious and costly work to produce a 3D computer generated urban model, especially when accuracy is important."

The challenge of modelling a virtual scene is to make it look real. It is more difficult if the model is based on an actual environment as comparisons can be

[13] William H. Jepson is director, UCLA Urban Simulation Laboratory Department of Architecture and Urban Design University of California, Los Angeles

made more easily. Visualising a large project gets more difficult as all the different components are added to the 3D model such as the buildings, roads and furnishings, which slows down computers, and increases the time scale of a project but, looking on the positive side, "once a 3D model has been generated it can be used for numerous purposes". According to Goldstein et al [2003] they can "provide insights into urban growth processes and are valuable for land-use and urban planners".

While software advances have made it possible for realistic visuals to become a possibility within the design industry," the process for creating these visuals is very time consuming, and therefore an intuitive and easy-to-use 3D modelling system has become more crucial with the rapid growth of computer graphics in our daily lives" [Sebe et al, 2005].

In order to make 3D visual representations of the real world appear realistic, reasonably accurate information is needed. "3D models in conjunction with textures are the most important part of computer graphics, nevertheless, despite their importance, no simple and fast method exists for creating 3D models of real-world objects" [ibid].

So the challenge, taken up in Chapters 4 through to 6, is the creation of a real world model that conveys sufficient information for observers to understand the environment depicted, to an acceptable degree of accuracy and within a budget that would be regarded as economic. A definition of what is economic in this sense is postponed to the concluding chapter.

The belief expressed in this literature is that Visualisation is an ideal method of presenting built environment issues to the public, while it also allows the architect, contractor etc, to view the developments prior to construction, analyze any problems, and make appropriate alterations before any construction commences.

The importance of improving the quality of design and resolving disputes in the construction process are key aspects of the 'Partnering' movement in the construction industry as well as in planning. The need to increase the percentage of those using 3D technology has been perceived by universities worldwide, who are now developing new degrees and courses specialising in the use of 3D visualization for the construction and planning industries.

In the construction industry, computer visualization can be used to present complicated construction information, such as materials, styles and types of components and structural information, in a way that is recognisable to clientele. These images can be presented as still images or short animations presenting the viewer with an 'all over view' of the generated model. In one of the following subsections this thesis will look at how animation can be used to aid public awareness within the planning process.

2.8 Defining some terms

Up until this point the terms '3D modelling' and 'visualisation' have been used somewhat loosely, but 3D simulations come in a variety of formats, powered by a range of platforms. In order to create a 3D model for the main experiment described in this thesis, it is necessary to select a platform from within this range. In order to do this, it is first necessary to understand the range of choices available. "Many types of visualization techniques now exist, ranging from traditional 2D, artistic rendering based on interpretation of conceptual project ideas, to 3D fully detailed animated simulation that completely illustrates all aspects of the project" [Garrick et al, 2005].

In general usage, the term '3D' simply means 'having three dimensions,' that is characterized by Cartesian (X,Y,Z) coordinates. At the top end of the scale there are technologies that provide the participant with a totally immersive experience at a life size scale. These technologies are given the generic title of 'virtual reality (VR).' According to Riva[14] et al [2003] "VR can be considered as the leading edge of a general evolution of present communication interfaces." At the other end of the scale are technologies that are neither virtual nor truly 3D yet have been adopted under the family name '3D Visualisation.' The next subsections examine these technologies in more detail: Virtual Reality (2.8.1), 3D Animation (2.8.2), Desktop Visualisation (2.8.3). The various terms are defined more specifically in the glossary.

[14] Associate Professor of Communication Psychology at the Catholic University of Milan, Italy.

2.8.1 Virtual Reality

"According to Bricken [1990], the essence of VR is the inclusive relationship between the participant and the virtual environment where direct experience of the immersive environment constitutes communication" [cited in Riva et al, 2003].

In 1999 Chen commented that "Virtual Reality can be seen as an interface technology between computers and humans" and that a "VR-based design environment can help break the barriers that lie between enabling both parties to visualise in an intuitive way what the planners have to propose and what the future effects may look like, thus improving the decision making process." This thought is also shared by several other researchers who also believe that VR makes 3D visualisation technology a popular tool for urban planning and landscape design applications (Pullar & Tidey, 2001; Schmid, 2001; Van Maren & Verbree, 2000; Waly & Thabet, 2003) [cited in Nicholson- Cole, 2005].

According to Lee et al, [2005] "Visual navigation of large-scale environments is one of the most important applications in computer graphics". We are all conscious of the space around us, and Giddings [2002] believes that VR technology can be used to "greatly enhance clients understanding" [Giddings, 2002].

So how is VR achieved? There are several different methods of viewing virtual scenery such as:

- Head-mounted displays (HMDs), that are similar to wearing a monitor over the users head. This method of viewing a Virtual World is restricted. It can only be viewed by limited numbers of individuals at any one time over physical networks of HMD's and therefore limits conversation when viewing a scene.

- Cave automatic virtual environment (CAVE) is another method of viewing Virtual environments and was first introduced in the University of Illinois-Chicago in 1992. This method of presenting virtual models allows the user to become immersed in the virtual world where projectors are directed to four, five or six of the walls of a room-sized cube. The CAVE method can present to a group of people rather than only an individual which gives room for discussions and conversations. The biggest technical disadvantage of this method is reflection from opposite screens.

Another disadvantage which is important when considering the authors research, is that this method is less accessible by members of the general public as the cost of creating such an environment would mean that they would need to travel to an area that already has the equipment set up for presentations. According to Christou[15] et al [2006], "Virtual reality (VR) and mixed reality (MR) technologies are now becoming sufficiently developed so that simulations of cultural or architectural sites, or virtual environments (VEs) for design are successful in making users feel truly immersed, especially within CAVE™-like displays utilizing head-tracking" [Christou et al, 2006].

- Panoramic Displays are another method of presenting to a group with the use of one or more screens and projectors panoramically arranged. These forms of projection may be used with '3D spectacles' to give enhanced impressions of depth.

In urban regeneration applications, VR can be used to generate an interactive environment which can communicate ideas easily to viewers, as they are given the sense that they are fully immersed in the new development long before it has been created. The field of Virtual Reality has allowed users, for the first time, to be fully immersed in a virtual world, and developments in the 21st century have now made the virtual environment a very near simulacrum of the real world. When VR was first introduced there were limitations in realistic representations of the virtual scenery. Advancements in realism facilitated by the latest rendering software and the development of faster computers and machines make the transformation between the virtual and what is real a much smoother process.

The possibilities inherent in the application of VR for urban regeneration are attested by a developing catalogue of examples, such as those created by the Urban Simulation Team (UST) at the University of Carlifonia Los Angelis (UCLA). These include the remodelling of LA after the riots in the 1990s, and the modelling of the Hollywood Entertainment District, an 18-block stretch of

[15] Chris Christou is from the Department of Computer Science at University College, Gower Street, London

Hollywood Boulevard from LaBrea on the west to Gower on the East which was contracted by Mayor Richard Riordan's Office of Economic Development. More examples of 3D regeneration projects can be found on the UCLA web site at http://www.ust.ucla.edu/ustweb/ust.html.

As an example of the development of VR, AEI Digital, an Architect firm from Philadelphia "Meticulously constructed" [Marriott, 2004] a virtual model, with more than 4 million polygons, of a Baseball stadium in Philadelphia, now called the Citizens Bank Park. Thousands of members and the general public were given the opportunity to tour the park before it existed. "They visited it virtually, gliding through a finely detailed, three-dimensional digital model." Although there were no "Crack of the Bat, the cheering of fans," or the "aroma of hot dogs and peanuts" [ibid], the virtual model proved to be a vital tool in giving "prospective investors a good idea of just how their company's name might look looming high above the park" [ibid].

However, there are problems with the mundane use of these technologies. Despite Christou's comments, these environments are not cheap, nor available, nor are they particularly portable.

As to cost, in 1991 the College of Architecture at Texas A&M University had "begun operating a state-of-the-art visualization laboratory for instructional and research purposes. This 4.5 million dollar facility occupies 4000 square feet...and utilizes an array of computer hardware and software to accomplish image generation, image manipulation, real-time computing, merging of media (computer-generated imagery, videotape, audio, still photography, animation), and data storage and retrieval" [Segnar et al, 1991]. Costs have fallen significantly since then, but even low cost environments are potentially beyond the reach of planning departments[16]. For example Swansea University created a CAVE more recently at a cost of £650,000 [Chen, 2007].

Herold et al [2005] identified a series of problems in "building, calibrating and applying models of urban growth and urban land use change. These relate to the issues of data availability and to the need for improved methods." The data capture demand of full scale, life size models are non trivial. VR in the sense

[16] The University of Georgia cut costs in producing their NAVE but still spent $60,000

described here is beyond practicability for the kinds of use that this thesis envisages for all but the most expensive or strategic developments.

Yet if a form of VR could be created at a lesser scale with much reduced 'grain size' in terms of real world objects, then it may become more practicable for the purposes described in this thesis. True immersion is lost as is 'life size', but interactive walkthroughs displayed on computer desktops are often described as a smaller scale VR (see section 2.8.3).

According to Brook [1999] "most workers consider desktop displays not to be VR as they do not display a scene in life size and do not give the illusion of being fully immersed in a virtual world." While it is true that a viewer is not fully immersed, the author believes that a person does not need to be fully immersed in an environment to feel immersed in that environment. On this basis it is perfectly feasible to build 3D virtual models for the personal computer that permit end users to identify with real environments.

For the purposes of this research, such systems are referred to by the generic terms '3D visualisation' or 'desktop visualisation' to distinguish them from VR (see section 2.8.3). Before considering desktop visualisation, it is helpful to first examine 3D animation.

2.8.2 3D Animation

The first form of animation was created by drawing a series of 2D representations, each one having a slightly different element to the last so that when viewed in quick succession it would give the appearance of movement. While the frame by frame or 'stop motion' approach is retained in digital animation, drawing is partially replaced by algorithms that compute sequences, and 2D geometry is often replaced by 3D geometry. In the case of 3D objects, computer algorithms are used additionally to render 3D wire frame models with photorealistic effects and to simulate depth of field, motion and shadow. Sometimes animated 3D simulations are referred to as 4D to reflect the notion of time passing as either objects move from the perspective of the observer, or as the observer 'moves' in relation to the object.[17] The process of creating a 3D animation can be divided into three stages:

1. 3D modelling describes the shape of an object
2. 3D rendering produces an image of an object
3. Layout and Animation describe movement and placement of objects within a scene

Originally animations were used entirely for entertainment or education. Today they are used for many purposes other than entertainment. For the purposes of this thesis, animation is about displaying 3D images in two dimensions using 2D media like a computer screen or film (animated holograms are still experimental and beyond the scope of this study).

As Russell [2002] suggests "3D graphics is a confusing term. Typically, it means that something is modelled in 3D but displayed on a 2D screen. Yes, you can manipulate objects to see hidden features, but you are still looking at a 2D screen...You can rotate the 3D object in front of you, but you can't walk around it" [Russell, 2002].

3D is represented in two dimensions basically by removing information about the third dimension: depth is removed and replaced with indirect information. The retina is a two-dimensional array of receptors but it permits the brain to recognize three-dimensional objects using perspective and information like shading.

Pixar, one of the leading computer animation companies to date, started its life in 1984 and created a string of short films such as 'Tin Toy' [1988], 'Knick Knack' [1989] and a number of commercials. It was not until 1995 that it produced the first ever feature length film. The film, Toy Story, was a massive success and illustrated the capabilities of the computer in producing a highly realistic, if not accurate, model of a whole environment, including all buildings, landscapes and human inhabitants.

[17] Eventually the development of 'true' 4D models are likely to become commonplace: 3D models changing over longer time horizons. This also has a planning dimension: creating models from "different periods in time is valuable for examining how cities grow and how policy changes influence urban dynamics" [Goldstein et al, 2003].

In 2001, Smallman et al [2001] suggested that there is "more to applying perceptual principles to display design than simply mimicking the retinal images of a scene as closely as possible." The more realistic the image the easier it becomes for the viewer to compare it directly to what they see in the here and now. However to further improve the idea of realism, animation can be used to "mimick" a sequence of images, creating a walkthrough that would allow the user not only to walk past a scene or building, but also around.

With the development of computer software packages such as ArchiCAD and Revit, it is possible for building design professionals to create rendered 3D models and to "walk" their audiences through or around a development before it is built, giving the viewer a glimpse of a potential future environment with which they may interact. This form of presentation allows the viewer to relate to a scene and get a sense of scale as well as of motion.

2.8.3 Desktop Visualisation

Desktop visualisation is a generic term that embraces the technologies that enable the development and display of 3D models on the personal computer.

Such computer displays are the cheapest means of viewing virtual environments. They are more accessible and can be displayed in public areas using a variety of screen technologies, accessed via the internet or made highly portable by the use of laptop computers. Delaney from the School of Environmental Sciences in University of East Anglia [2000] spells out the vision: "Urban planning is made much easier when simulations are used to present projects. Walking through a virtual version of a proposed development gives one the sense of actually being in a place, unlike looking at the architects' conventional physical model".

Essentially, desktop visualisation is a synthesis of VR and animation technologies on the desktop. For example, the same basic 3D model constructed as in steps 1 and 2 above for animation, can be imported into software that allows the user to interact with a scene and become almost immersed in the artificial environment (hence the slightly misleading term Desktop VR). In this form of visualisation, the user appears to have a degree of freedom or control as they manoeuvre through or around the model, panning and zooming at their own discretion. Examples of this can be seen on estate agency web sites, now rapidly becoming normative, and allow viewers to see 360 degree photographs of rooms within a home so that prospective buyers can take a "virtual tour".

Desktop visualisation is therefore an emerging suite of tools and software products, which are capable of representing simulated or real 3D environments. The advent of desktop visualisation offers the prospect of a significant upsurge in the use of 3D models as costs fall. Where data is cheap and easy to collect, as in the example of photographs of properties for sale or re-usable virtual worlds, this upsurge has already happened. Where data is more complex and data capture offers more significant challenges, as in the modelling of real environments for use in construction and planning, the promise of 3D visualisations is being realised more slowly.

Nevertheless there are two key sources of data that may help to make the transition to 3D modelling of urban environments more economic in the short term. First there is a considerable amount of data derived from 2D CAD modelling of new developments that has become established in the last two decades. This data can be used as the basis for 'growing' 3D models. Secondly, there is much terrain data that has been captured by diverse means for use in Geographic Information Systems (GIS). The potential clearly exists for the marriage of building and terrain data in developing models, as will be demonstrated in later Chapters.

In 2002, in an article entitled 'Bringing 2D to life' it was suggested that, "The time it takes to create a model is disproportionate to the benefits the project architects gain. The need to make the creation of the 3D model easier appears to be of paramount importance" [ANON, 2002]. While the author agrees that the need for easier methods of model generation is crucial to the economic implementation of 3D modelling, it is no longer the case that the time required for model generation is always "disproportionate to its benefits."

Furthermore, also in 2002 the writer of 'Beyond the Realms of Design' explains that "Although the time required to initially create 3D models can be longer than the traditional 2D method, the subsequent time to carry out design changes and reflect these changes in the associated 2D plans, sections and elevations is greatly reduced" [ANON 2002a].

In 2003, Bill Ribarsky in his article "3D Reconstruction and Visualization" predicted that there will be an "exponential explosion in the amount of data available for analysis and exploration" and suggests that future models will be so detailed that they will include "buildings and everything associated with the environment, such as trees, shrubs, lampposts, sidewalks, streets, and so on" [Ribarsky, 2003]. While this 'explosion' will be a great aid for those currently unable to understand current presentational techniques, giving members of the general public a more accurate and realistic view of things to come, it remains a future explosion. For most practicable real world projects, data capture remains a significant issue as this thesis will demonstrate.

"Realistic visualization is of special importance if the results are to be presented to the public" [Herold et al, 2005]. "Computer visualisations clearly have the potential to project what local landscapes under various climate change conditions might look like in the future" [Nicholson-Cole, 2005]. Although Nicholson-Cole[18] [2005] is focusing on the use of visualization to communicate climate change, these comments are still very relevant to any areas where real world 3D information needs to be communicated to the public.

So, while the technology of desktop visualisation is sufficiently mature to produce accurate models of the real world, data capture remains a key issue. Given also that this technology is still emerging, interoperability between software products and the file formats they create is also an issue, especially in the interface between CAD and GIS, as this thesis discloses.

These difficulties are not deterring the "pioneers" as the following examples demonstrate:

- An early example of the use of 3D computer modelling for urban regeneration was in Cerritos, Americas in 1999, when an expansion of a library resulted in the need for a two storey car park facility. The local city officials were reluctant to approve the proposal as it was adjacent to a residential area. In order to overcome this set back the council asked MultiGen-Paradigm the leaders of 3D GIS Solutions in the USA, to create a

[18] Sophie Nicholson-Cole is from the School of Environmental Sciences, University of East Anglia, Norwich.

real time 3D simulation so that it could be displayed to neighbouring communities. "The real time 3D simulation allowed viewers to take a realistic 'walk' through the model. As a result, the neighbouring community were made aware and as a result the car park was built beneath the ground for an extra $2 million. The 3D model was created by Multigen. Example can be found on their web site. http://www.multigen.com/solutions/urban/ cerritos.shtml.

- In British Columbia, "forest managers increasingly depend on computer-based landscape visualization tools, to visualize the effect of different scenarios" [Lewis et al, 2005]. This allows the forest managers to evaluate which development scenarios least affects the plantation, while allowing designers to pinpoint the most effective developments.

- Researchers from Norfolk USA and East China have written an article discussing a model they produced of downtown Denver where "users can easily view building details, or an entire city in a moving 3D, or locate a specific building, and so on. This technique will bring current 3D GIS city modelling into a new era of development" [Zhou et al, 2004]. The finished model can be viewed on the web site[19].

As the use of 3D visualization becomes more widely known, users of this software become more demanding. As computer visualisation technology develops, the demand for visual presentation will, in the author's opinion, undoubtedly increase. Publicity from construction programmes such as 'Building the Dream' broadcast in June 2004 on ITV, gave viewers an insight into the design and construction industry. The programme allowed contestants to discuss design ideas, choose architectural and interior materials, and view a 3D model giving an insight into how a "million pound home" would appear once completed, therefore making "visible what was invisible to the human eye" [Kerlow, 2004].

Although the use of VR may be effective in regards to promoting understanding of proposed developments, it is however an expensive visualization tool, due to the required apparatus, and as a result is not always considered a feasible option for

[19]http://images.google.co.uk/imgres?imgurl=http://www.vexcel.com/images/press/den_trx3.jpg&imgrefurl=http://www.vexcel.com/company/press/archives/3d_city_models.html&h=600&w=800&sz=249&hl=en&start=2&um=1&tbnid=hMYS-F2rqBhgjM:&tbnh=107&tbnw=143&prev=/images%3Fq%3Dvexcel%2Bdowntown%2Bdenver %2B%26svnum%3D10%26um%3D1%26hl%3Den

design professions such as Architecture. As discussed above, Desktop displays are the cheapest form of VR displays, and can also be used to reach a wider range of people with the use of the internet. The use of 3D Computer Generated Models across the internet could significantly enhance public participation in the planning process.

2.9 Conclusion

This chapter considered issues of the general public and their right to judge, refuse, and participate in future developments within their home, village, town or city, and "while there is a statutory requirement for the public to be involved in the planning process this is all too often limited to a fairly basic level of participation. It has been suggested here, that all members of the public, regardless of education and status, should "be allowed to take a fuller part in planning decisions that affect their communities and lives" [cited in Friends of the Earth, ANON, 2005a].

A survey carried out by Duncan et al [2000] outlined that less than a third of "Initiatives" involved the local occupants, and addressed the facts that getting the local community involved early can have a significant impact on the long-term sustainability.

Furthermore, this Chapter has looked at how, over the past ten years the Government has put great emphasis on encouraging communities to take part in future developments and regeneration projects, and also suggested that planners and council members should ensure that the public are given early and effective opportunities to participate.

Other issues highlighted in this chapter discussed other research being carried out in regards to the use of 3D visualisation within the planning process, and research into the use of 3D modelling within urban design has been found as far back as 1991 and even further.

The main focus of this chapter however, has been to highlight the need for the use of 3D visualisation as a means to enhance public participation. The belief here is that Visualization is an ideal method of presenting to the public, and would be beneficial to aid public participation within the planning process. This is an opinion which has been shared by many researchers such as Piekarski et al, [2005], Laing et al [2005], and Kirkey, [2005].

Although there are many academics who agree that 3D visualization will be an asset within the planning process to enhance participation, to date there has been no proof that any research has been carried out which asks the public's opinion on how they would like to participate, the methods used, and how these methods should be improved.

As a result the major study of this research will focus on the needs of the public in regards to helping them understand developments, and to determine whether using 3D technology will increase participation.

In this thesis, 3D models are created that are capable of running in PC environments using animations. Following the lead of the Advisory Group on Computer Graphics (AGOCG), an initiative of the Joint Information System Committee (JISC) the models created here are labelled as VR/Animations. They are labelled as VR despite the reservations expressed in this chapter about the proximity of these systems to true VR:AGOCG refers to them as "the least immersive implementation of VR techniques." They are labelled as animations because they have removed the ability to navigate from the end user. Far from being a disadvantage this was viewed by the author as an asset because of a desire to ensure that a minimum of computer skill would be required when members of the public view potential developments via this medium.

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Chapter 3: Survey - The supply of 3D visualisation services in Wales

The previous Chapters have shown that common techniques used to showcase developments to the general public are not always effective and that it is theorised that 3D technology will help to enhance public participation within the planning process. How prepared are BDP firms to supply these services?

According to Garrick et al [2005] visualization is a communication tool that can be used to enhance participation within the context of public involvement and "can be effectively used at all stages in a public involvement Process" [Garrick et al, 2005]. However, as previously discussed in Chapter 2 of this thesis, following a discussion held with Mr Gareth Hall, the Director of the Department of Environment, Planning and Countryside for Rhondda Cynon Taff, it is evident that 3D technology and visualization is not being adopted within the planning process in RCT. In fact this picture typifies Wales more generally. Mr Phillip Hall, Chief Technical Officer at Cardiff County Council, confirmed in a telephone interview that local authorities in Wales had not yet adopted 3D visualization techniques. The only potential use of such techniques was to model the Olympic Facilities at Cardiff, but tender documentation had not yet been drawn up in May 2007.

This chapter will discuss a preliminary survey during September/October 2003 which targeted the Building Design Profession in Wales, and aimed to establish which computer software packages were then being utilized and for what purpose. If as this thesis contends, 3D modelling is needed, it would be necessary to establish that capacity existed among BDP firms to offer 3D services. If the capacity did not exist it would then be necessary to try and answer the question 'why not'? Indeed it would be useful to try and identify obstacles to the process, examine their nature and develop a program for capacity building. The survey was conducted using a questionnaire which is described below.

3.1 Questionnaire Design

The aim of this questionnaire survey was to identify how many BDPs utilise 3D technology, and which applications software is used and for what purpose. It also aimed to identify any problems that may have been encountered when using their selected 2D or 3D software applications.

In order to encourage a good response rate, the questionnaire was sent by mail with a return address, and free postage provided. The design needed to be simple to follow, easy to understand and precise in what it was required to achieve [Thomas, 1996] to encourage respondents to remain focused on each question.

The questionnaire was printed on both sides of a single sheet of A4 paper and was folded so that the central portion contained the University of Glamorgan Freepost address. This seemed to be an economic use of space and should not appear to be too demanding in the hands of a recipient: Bryman and Bell [2003] discuss the requirement for economy in the face of evidence that suggests some hardening against participation in surveys.

The questionnaire contained some open-ended, but predominantly closed-ended questions which allowed the respondent to tick a 'yes or no' box. The open-ended questions allowed the respondent to express their opinions, if desired, in relation to their current software, and their attitudes on the advantages or disadvantages of using 3D images, and real time animation for the purpose of presenting designs.

'Tick' boxes were used to elicit the names of software products in use. Lists were populated using the authors own experience of different 3D CAD software and add-on applications, coupled with an investigation of software currently available on the market. As there is a large variety of 3D CAD software products, not every product could be listed on the questionnaire, so an 'other' tick box was provided allowing the user to list any additional software.

Questions of an open-ended nature were kept to a minimum, and were used primarily to identify any issues relating to their current software, and opinions regarding the use of 3D software applications within the building design process.

A specimen copy of this questionnaire can be found in Appendix 2.

All the data was coded in SPSS and reports of descriptive statistics were generated. The data was exported to Microsoft Excel to create the graphs and tables that illustrate responses.

3.2 Other Surveys Conducted

There was already evidence from a number of UK studies that capacity was beginning to develop, but that the use of 3D technology remained a marginal activity. For example, in 2000 Susan Smith from Architecture Weekly discussed a survey which was conducted by Kristine Fallon Associates in Chicago in 1997 and again in 1999. The results of this survey showed that 100% of the Architects, Engineers and Construction (AEC) Companies were using AutoCAD.

In 2001 a survey conducted by Azar Arif and Ally Karam investigated the use of CAD software outside the UK. The results of this survey showed that the most popular CAD software used in South Africa at that time was AutoCAD with 44% of respondents utilizing the 2D software package. Their survey also showed that AutoCAD was the most popular software in Canada, Scandinavia, Denmark, Finland and Sweden.

Robert Green, Manager of Cadalyst magazine produces an annual survey to divulge what the most dominant software package is in use in the UK. His findings showed that in 2003 AutoCAD continued to be the most frequently used CAD package at 54% although in 2001 the percentage was as high as 75%. The only numerical increase was for MicroStation, which roughly doubled its share of users to 4%. In 2004 Greens survey showed that "as has been the case in all past surveys", ArchiCAD and Revit, two important 3D software applications, both had fewer than 6%.

Green concluded his 2004 survey by stating that "a lot of people out there are running their businesses on AutoCAD, even 23 years after its beginning". It seems that "No matter the reason, 2D still rules and totally 3D design-enabled businesses are in the distinct minority." [Green, 2004]

These survey examples illustrated the use of CAD in professions throughout the UK and world wide. The survey which will be discussed in this chapter will focus on the BDPs based in Wales.

3.3 Survey of Welsh BDPs

In order to identify BDPs in Wales, first the term BDP needed to be defined by reference to a series of groups that were likely to have adopted these technologies. Given the notion that public participation should begin early in the planning process, BDP is here defined to include Architects, Interior Designers, CAD Technicians, Property Developers, Engineers, and, Surveyors, all of which are likely to have an input into urban regeneration projects.

The next step was to conduct a search to identify professionals in each of these groups using business directories and Internet Yellow Pages. A sampling frame was then created in Excel, the firms were listed by groups and random numbers generated for each firm. A quota of 50 of the top randomly generated numbers from each group was then selected and targeted for the questionnaire described above, 300 questionnaires in total. The questionnaire was sent to the target respondents along with an information sheet explaining the purpose of the research.

One month was given for all responses but, despite the economic layout of the questionnaire, only 19 of the 300 questionnaires sent were returned within the time scale. This represented a 6.5% response rate. As a result, a further 50 questionnaires were sent to building design professions, and after a further month only 11 more questionnaires were returned, which still represented a very poor response rate.

Due to the poor response, the author sent a reminder to those who had not responded, via email, where the email address of the company could be found; the questionnaires were then sent as an attachment in a Microsoft Word format, which allowed the questionnaire to be edited and returned via e-mail. "The rapid diffusion of the internet in recent years has brought in its wake a new method of conducting opinion polls" [Sparrow, et al 2003] and this proved to be a much quicker and easier method of sending questionnaires. However, only five further responses were returned within a week, and no others were returned after this period. This gave a total of 35. Finally, the author decided to pursue recipients over the telephone, to target the sample who to date (December 2003), had failed to respond. Eventually 47 responses were received, 3 of which were subsequently labelled as non-responses because they did not supply sufficient amount of the required data. When all responses had been received it was possible to commence the analysing process.

Microsoft Excel and SPSS were chosen because they are common, standard software for quantitative analysis. SPSS numerically codes responses and numerical characters were assigned to represent every permissible answer to coded questions, all missing data was represented by '0'.

A link was created between Excel and a Word document, where details such as names of respondent or company, if provided, and opinions given for open ended questions (Question 15 to 17) could be stored. A representative sample of these open ended responses will be discussed in Section 3.5 of this Chapter.

3.4 Results and Analysis

During this sample, 44 valid responses were achieved from BDPs in Wales. For the population identified, a confidence interval of between 12 and 13 is suggested by the sample size at the 95% confidence level. This was disappointing and suggests caution in terms of generalising from the results.

In order to compare the results obtained with the previous surveys referred to above, it would be necessary to count only Architects, Architectural Technicians Interior Designers and Engineers. Indeed if this is done, the results from this study show a similar take up of these technologies to the rest of the UK suggesting that despite the small sample size a useful approximation to the population has been identified.

The majority of the respondents were Male: 65.9%, 31.8% were female, and 1 did not respond to this question.

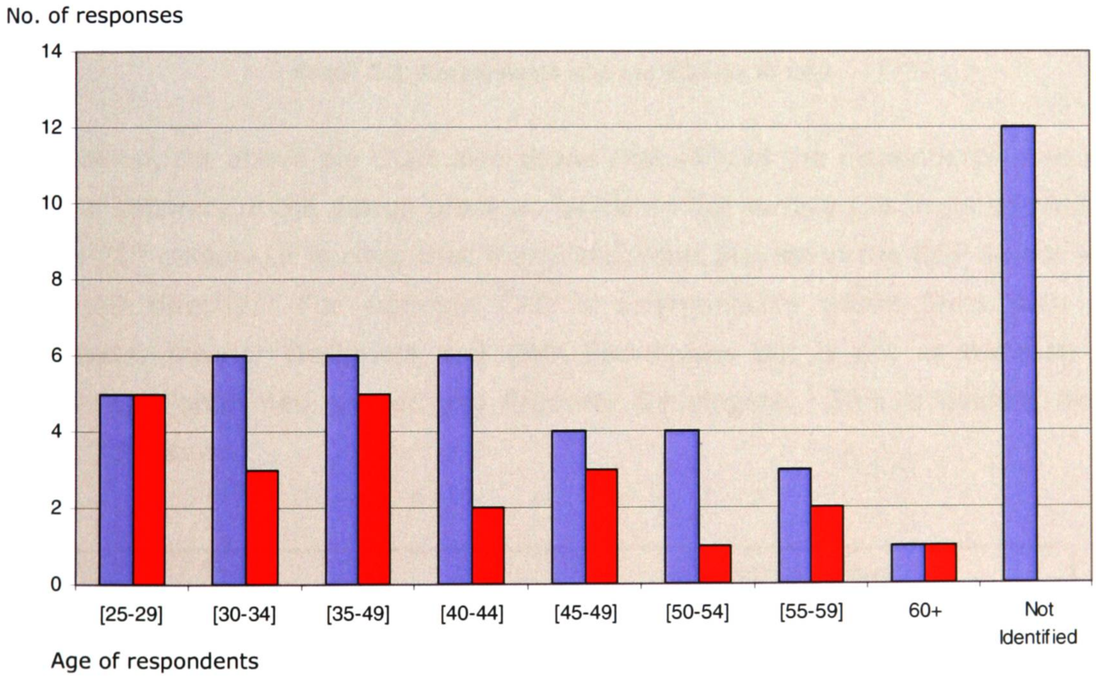
Table 3.1 below shows that the majority of respondents were CAD Technicians (22.7%). 20.5 % were Property Developers. 9.1% were Engineers. And 15.9% were Architects and Interior Designers or Surveyors.

	Architect	Interior Designer	CAD Technician	Property Developement	Surveyor	Engineer
Male	6	3	10	4	3	3
Female	1	4	0	5	3	1

Table 3.1: Gender and Occupation

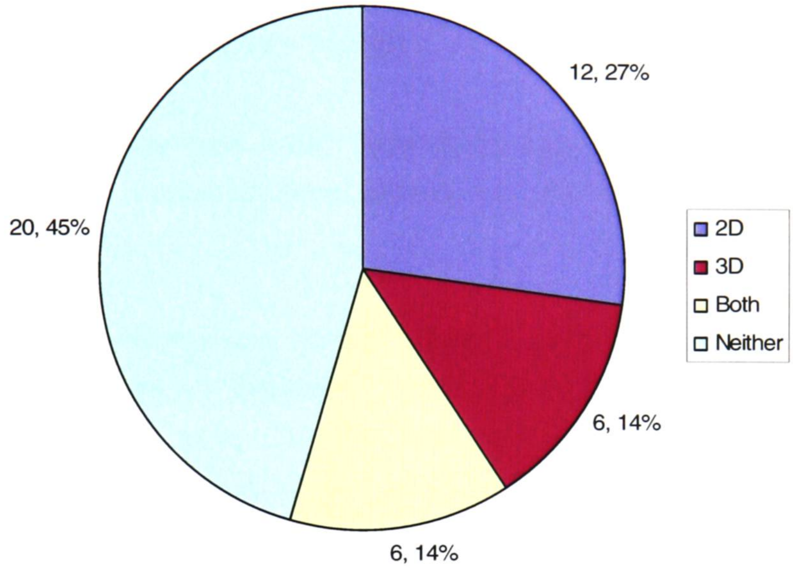
The majority of Male respondents were Architects and CAD Technicians, where the majority of women were Interior Designers and Property Developers.

Graph 3.1 shows the number of respondents within each age group (in blue) and the number of respondents using 2D and/ or 3D packages (in red).



Graph 3.1: Age of Respondents

When the respondents were asked whether they use 2D or 3D computer software packages at their place of work, the response showed that 27% of Welsh BDP's currently use 2D CAD and only 14% used 3D computer packages with a further 14% using both. This has been illustrated in Graph 3.2 below.



Graph 3.2: Respondents who use 2D and 3D CAD

In addition, the above pie chart also shows that 45% of the respondents used no form of software in the design process. While on the surface this looks surprising in the 21st century, it is clear that many important players in the BDP do not yet use CAD directly. For example CAD is commonplace within firms such as Architects, Interior Designers and CAD Technicians but is not as common in Surveying Companies and among Property Developers. This is evident from Table 3.2 below.

		3D or 2D Dimensions			
		2D	3D	Both	Neither
Company Type	Architect	4	2		1
	Interior Designer	2	3		2
	CAD Technician	5		3	2
	Property Development	1			8
	Surveyor			1	6
	Engineer		1	2	1

Table 3.2: Comparing Company type and the use of CAD

This clearly has something to do with traditional business models: for example, developers have historically seen themselves as the client of technical CAD services. The perpetuation of such models must be doubtful in an age when Universities are training many more surveyors in CAD techniques and, indeed, as CAD software become more user friendly.

Regardless of company type, most respondents could see the benefits of creating a 3D model for a proposed development, yet not many have embraced the technology.

From the 6 who currently use 3D technology 2 were Architects, 3 were Interior Designers and 1 was an Engineer. From the 6 who used both 2D and 3D software packages, 3 were CAD Technicians, 1 was a Surveyor and 2 were Engineers.

The main use of 3D technology by BDPs is to display 3D designs of Refurbishments, Planning Applications and generally providing visualisations to the client as shown in Table 3.3 below. This small cohort can be identified as the existing capacity to develop 3D visualisations for public participation. It is a small step from producing visualisations for client to producing them for public consumption. As visualisation becomes more widespread as a marketing tool, opportunities for use in consultation increase.

	Frequency	Percent
Planning Application	4	9.1
Space Planning	1	2.3
Refurbishment	2	4.5
Detailed Designs	3	6.8
Mechanical Design	1	2.3
Visualization	3	6.8
Other	1	2.3
Don't Know/Not Applicable	27	61.4
Missing	2	4.5

Table 3.3: The uses of 3D Technology

Those respondents who only use 2D CAD, used it to produce drawings for planning applications (38.6%), detailed designs (9.1%), and refurbishments (6.8%). This can be seen in Table 3.4 below.

	Frequency	Percent
Planning Application	17	38.6
Refurbishment	3	6.8
Detailed Designs	4	9.1
Mechanical Design	3	6.8
Other	1	2.3
Don't Know/Not Applicable	13	29.5
Missing	3	6.8

Table 3.4: The uses of 2D Technology

From those who do not currently use 3D technology within their place of work, the reasons given were; expense of software, expense of training, and the time required in producing models. The questionnaire also asked respondents to consider whether they would convert to using 3D technology in the future. From the 44 respondents 34.1% suggested that they would use 3D technology if there was a demand to do so. From the 12 respondents who only use 2D outputs (10 Male and 2 female), 50% suggested that they would convert to using 3D technology in the future, if it was required.

From the 20 respondents who do not use any form of Computer based design, as little as 15%, one Interior Designer, one CAD Technician and one Property Developer, suggested that they would use 3D in the future, another 15% were not sure.

In regard to the most commonly used software package, whether for 2D or 3D outputs, the results of this survey sample showed that AutoCAD, a software application which can be used to create both 2D and 3D line drawings, was the most popular software adopted by the BDPs, with an overall percentage of 25%. This has been illustrated in Table 3.5 below. Removing the 45% who do not use any form of CAD increases the total of AutoCAD users to 46%

	Frequency	Percent
AutoCAD	11	25.0
ArchiCAD	1	2.3
Microstation	1	2.3
3D Studio Max	2	4.5
TurboCAD	1	2.3
Other	3	6.8
Don't Know/Not applicable	3	6.8
None	16	36.4
Missing	6	13.6

Table 3.5: Utilization of 3D software

The 'Other' software listed, were; UniGraphics, Metalsoft Fabriwin with a DXF Converter/Importer, Pro Engineer, Mechanical Stress analysis application and Lightscape. Table 3.6 below shows the software adopted by different company types, and shows that Architects and CAD Technicians are the main users of AutoCAD in regards to this sample.

	Auto-CAD	Archi-CAD	Micro-station	3D Studio Max	Turbo-CAD	Other	N/A	None
Architect	3	1						1
Interior Designer	1			1	1	1		2
CAD Technician	4					2		1
Property Development			1				3	5
Surveyor	1							6
Engineer	2			1				1

Table 3.6: 3D software and purpose of use

In regard to add-on packages, they were used by 25% of those surveyed. The most commonly used add-on application was Photoshop with 11.4%, which is used to manipulate and improve images. Other add-on software applications used were Corel Draw (2.3%), and Architerra (2.3%) used to create 3D terrain and highways. The 'Other' Add-on packages listed included Artlantis, a rendering application.

When questioned, several respondents suggested that the software had been chosen as it was the most suitable for the company's requirements at the time of purchase. However it was suggested that if the companies were to grow, those who did not currently use 3D technology (72.7%), would consider converting to using 3D technology if there was a demand to do so.

The questionnaire concluded with an open-ended question requesting the respondents to provide their opinion of 3D computerised imagery. In relation to the use of 3D CAD, respondents have noted that its use allowed lay-people to understand and contribute to designs, as it allowed the untrained eye to get a sense of the finished environment, and was viewed by some respondents as being of great advantage to all involved in the design process. Not all the BDPs considered 3D CAD technology as an advantage, it seems that some respondents found the software difficult to use and it was suggested that the use of Hand Drawn Images gives a warmer appearance.

3.5 Responses to Open Ended Questions

A respondent from 'ProCAD', CAD Technicians based in Hengoed, South Wales, stated that when 3D visualization is used clients can see what they are getting. He continued to say that 80% of clients will not understand a project if they are shown a 2D image, and that a 3D computer generated prototype would "allow clients to see the results before it is created, and therefore is of great advantage to all involved in the design process".

A respondent from CAD Technicians, 'Concurrent', based in Newport, South Wales agreed, stating that "basically people have difficulty viewing 2D, and 3D helps to communicate what is being sold." However, although seeing advantages to 3D CAD, the respondent admitted that their staff prefer to make physical models "as they can be touched".

Mr J.C. Dabbs from the Engineering company, 'BDM Client Partnership' based in Monmouth suggested that "3D CAD has meant that people not trained to read 2D drawings, can understand, contribute and assess products before they are made. 3D Visualization and Walkthroughs are of most importance to clients. 3D is even more important for Building and Urban applications".

Another respondent suggested however that he believes that 3D Design is complex to use and appears cold to the client, he prefers to use freeHand Drawn Images as they appear warmer and friendlier."

A respondent from E2L Engineering Design Consultancy based in Monmouth agreed, stating that although he believes 3D CAD to be a good product it has become apparent to him that modern society "rely on pretty pictures instead of solid facts." However he did suggest that he would use 3D in the future but only if the company needed to develop to become more competitive.

Ms Owen of 'Maureen Kelly Owen Interior Design' based in Penarth in South Wales is a qualified Architect and is now the sole owner of her own Interior Design company. She works mainly using free hand drawings but commented that "It is amazing how few people have the ability to visualise in 2D, 3D software is amazing in conveying visual information". Ms Owen would consider using 3D CAD software if there were more textures and colours available, but she also believes that Computerised 3D images look "mechanical."

These quotations illustrate the kind of mixed response to technologically driven change that characterises most professions. Some see the real potential of the new technologies and embrace them. These early adopters or pioneers are always in the minority and run quite high risks. Some suggest reasonable grounds for a fear that 3D models might erode quality. But even where the predominant reaction is negative, firms keep a watching brief, ready to change at the point when a market matures ~ when they have to. Several firms here allude to a lack of demand and identified a readiness to adapt if demand materialises.

Despite awareness of the potential, the use of 3D modelling within urban development is very much in its infancy, and Wales is not untypical. There is a road to travel between the realisation that this technology may help, and its actual adoption.

At the outset of this programme of research, a useful lesson was learned. The author was commissioned by the University of Glamorgan, in conjunction with the 'Welsh Transport Research Centre' (WTRC) to produce a model of a route between the University and the local train station. The aim of the model was to illustrate the impact of erecting signage and painting fences and lamp posts in the University's colours along the route to the University. The model was commissioned as a means to help representatives of the community to visualise how the finished route would look, and to show that these changes would not significantly impact on their community. The model was well received and objectives were met. The development subsequently happened and the expenditure on the model was vindicated.

As a consequence, the author was subsequently asked to demonstrate the model (along with early versions of models produced for this thesis) to the Pontypridd Town Forum. This meeting was attended by council leaders, planners, developers and important local businesses. It was clear that the technology had a major impact on the audience, many of whom were experiencing the technology for the first time, and all of whom were seeing its application within the context of urban regeneration for the first time. One of the immediate outcomes was discussion about the commission of further work by the local authority. It rapidly became apparent that the data requirements for the model that they specified would be very demanding. Already the research was beginning to establish difficulties in adopting terrain data and incompatibilities with software formats. The only sensible decision seemed to be to choose the research at the expense of the potential consultancy at that time.

The lesson learned was that demand for 3D visualisation services will be significant. The benefits are self evident so that lack of demand is not likely to be a barrier. But as with other fledgling services, there is a need to identify clearly defined processes, quality controls and cost models.

One of the clearest conclusions from this survey is that BDPs in Wales had not undertaken analysis of potential demand and were not actively marketing 3D visualisation services.

This lack of leadership persists. For example at a recent conference held in Wales and hosted by Wendy Boddington Technology & Innovation Regional manager of the Welsh Assembly Government (WAG), it has become apparent that only a few companies are currently adopting 3D technology. During this event it was evident that although 3D technology is being used, it is not wide spread. Interestingly this Conference revealed a threat to traditional BDPs. A firm whose principal business is in animations, was very keen to move into urban environment models. Business threats often come from unexpected sources!

3.6 Summary and Conclusion

According to Segnar et al, [1991] a number of American construction industries started "utilizing, visualization technology in their operations as far back as 1991." Surveys conducted by other researchers around the world, demonstrate that over the past decade BDPs have embraced the 2D CAD method of presenting plans and elevations. "Indications show that the technology is no more considered an excessive expensive luxury tool, but rather a necessity that offices are starting to invest in both human resources and in financial terms" [Arif et al, 2001].

This Chapter has discussed a survey carried out with the use of a questionnaire, conducted in September 2003, to gather information regarding the use of computer software within the BDP.

When the respondents were asked whether they use 2D or 3D computer software packages at their place of work, the response showed that 41% of Welsh BDPs currently use 2D CAD and 28% used 3D computer packages. The most commonly used software package, whether for 2D or 3D outputs, was AutoCAD, and Photoshop was the most popular Add-on package.

It was also established that most of the respondents could see the benefits of creating a 3D model for a proposed development, but not many have embraced the software. For those not using 3D technology (72%) the reasons given were related to the cost of purchasing software, training and the lengthy modelling process.

Are these impressions correct? Is the technology prohibitively expensive? Is training, or rather the lack of it, a real barrier? Is modelling so difficult and long winded that economic services are not yet possible?

The following Chapter will focus on the usability of several software packages in an attempt to establish whether 3D technology is attainable for Welsh BDPs or whether it really is too expensive and too long a process.

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Chapter 4: Building Modelling

During the course of this research, several computer packages were tested for their ease of use, quality of 2D and 3D outputs and their ability to import data from relevant formats. This trial involved each software package being used to create a 3D model of an existing building within the Pontypridd area. The purpose of this trial was to examine whether some of the currently adopted software tools used within the Building Design Profession, discussed in Chapter 3 of this thesis, are capable of producing 3D models for urban regeneration. In the process the perception of BDPs elicited from the Survey in the last Chapter (Cost, Time and Training) were tested. The software packages used for this trial were packages from both ends of the market spectrum.

Section 4.1 discusses a trial conducted to evaluate various software tools in the context of modelling an existing building. Section 4.2 focuses on the use of Revit, which was chosen as the most favoured software from the trial, to model a proposed building and the processes involved.

4.1 Modelling an Existing Building

2D and 3D CAD packages have evolved dramatically from those first introduced in the 1960's [Whyte 2002]. One of the first packages introduced was 'Sketchpad', as discussed in Chapter 2, development in this technology since the 60s has allowed users of 3D computer packages not only to model elements of the world as it is today, but to model the environment how it once was, and how it may appear in the future.

In the 1970s, the University of North Carolina created the first interactive architectural walkthrough [Day, 2001], which led to the development of current (2003 - 2007) 3D Computer software packages.

"The leading developers of 3D architectural software packages to date, include Autodesk, Bentley Systems and Graphisoft who have marketed their products for modelling the built environment, as either 3D single building modelling (SBM) which includes Architectural Desktop from Autodesk and Microstation from Bentley Systems, or 3D Virtual Building Modelling (VBM) for example, ArchiCAD from Graphisoft" [ibid]. From 2003 onwards Autodesk and Bentley Systems re-launched their associated 3D SBM packages as Building Information Modelling (BIM) packages.

These packages are constantly being developed to improve outcomes and tool efficiency. Pollefeys et al [2002], stated in 2002 that computer graphics "are so advanced that they allow the user to render complex 3D scenes in real time". Since 2002, there have been numerous developments, and during the four years of this research, which commenced in 2003, there have been several released versions of the software used in this trial. For example, the AutoCAD version used in this trial was version 2004, however since then three higher versions have been released.

The following sections describe how an existing building was modelled in 3D.

4.1.1 Modelling an Existing Building with the chosen software packages

The software used in this trial is illustrated in Table 4.1 below.

Built Environment Design	Modelling & Rendering
AutoCAD 2004	3D Studio Max v5
ArchiCAD v8	Gmax
Revit v4	
Microstation v8	
TurboCAD	
3D FloorPlan v6	

Table 4.1: Software used

The table lists 10 software programs, including Microstation, which, due to time constraints and the delay in software purchase, was eventually removed from this trial. The software programs listed were chosen as they were the leading market products. AutoCAD, 3D Studio Max, ArcGIS and ERDAS were used, as they were already in use at the University. GMax was a free software provided by Graphisoft and was added to the table later on in the research. ArchiCAD was the most popular BIM package at the time and Revit was designed by developers who had worked with ArchiCAD, therefore a comparison would be interesting.

In order to analyse the softwares' 3D modelling abilities in regards to realism, the easiest method would be to commission a modelling firm to generate each model, as demonstrated by Alejandro Carvajal from Reading University, during the third international conference on the Innovation in Architcture, Engineering and Construction (AEC2005) held in Rotterdam.

However, the trial needed not only to show the outcomes but also to analyse the process of achieving these outcomes, therefore the trial needed to be carried out by the author so that the modelling process, the ease of use and the 3D outcomes could be analysed fairly. Another option would be to attend training for each software, to make the learning process easier, but in chapter 3 of this research the author discussed the findings of a survey exploring the current software trends within the Building Design Profession. The results showed that BDPs were reluctant to use 3D modelling packages due to the cost of purchasing and training, therefore a decision was made that each software would be learnt using the softwares' 'Help' menus, and tutorials available free with each software package.

Prior to this research, the author had only used AutoCAD 2000 and 3D StudioMax 3.1, which were used during a first degree at the University of Glamorgan. When completing the degree these skills were developed further when both software packages were used in the creation of a 3D model of the Railway station next to the University of Glamorgan, which was previously discussed in Chapter 3, Section 3.5 of this thesis.

No BIM packages had been used prior to this research, therefore ArchiCAD, Revit and 3DFloorPlan needed to be learned from the beginning. The same amount of time was allocated to learning and using these products. The modelling processes within ArchiCAD, Revit and 3DFloorPlan were very similar and once ArchiCAD had been learned, it was easier to learn Revit and 3DFloorPlan. Gmax was almost identical to 3D Studio Max, and TurboCAD, followed the same general principles as AutoCAD.

4.1.2 Software Analysis

For the purpose of evaluating these software packages, criteria's were developed and a table was created for each of the products used, briefly outlining the author's opinions regarding the different areas of each package. These criteria included ease of use, the 2D and 3D functions, printing properties and quality, visualisation and realism, and the helpfulness of the 'Help menu' and tuitions. A score out of ten was given for each section.

A subjective marking scheme for grading these different pieces of software was based on how easily a function could be carried out, the length of time needed to carry out a function, the quality and usefulness of a function, and the reliability of a function. The marking Criteria for each function has been shown in Table 4.2 below. A maximum of 2 points can be rewarded for each of the different processes within each function. These processes and the marking schemes can be seen in column 2 and 3 of Table 4.2 below.

2D Ease of use	Process of using 2D lines	0 - 2
	Method of selecting 2D commands	0 - 2
	Selection of Line types	0 - 2
	Hatch/Pattern selection	0 - 2
	Dimensioning	0 - 2
3D Ease of use	Process of generating 3D objects i.e. walls	0 - 2
	Method of selecting 3D commands	0 - 2
	Process of inserting objects i.e. windows	0 - 2
	Choice of construction types	0 - 2
	Collision Detection	0 - 2
Toggling between 2D/3D	Process of changing from 2D to a 3D view	0 - 2
	Rotating 3D view	0 - 2
	Visualisation in 3D View	0 - 2
	Selection items in 3D view	0 - 2
	Editing in 3D View	0 - 2
Plotting/Printing	Print Quality	0 - 2
	Printing Process	0 - 2
	Definition between lines on print	0 - 2
	Available templates	0 - 2
	Editing Paper size/ Border/ Text	0 - 2
Visualisation	Choice of visualising 3D views	0 - 2
	Realistic representations	0 - 2

	Availability of sun locations	0 - 2
	Setting up an image	0 - 2
	Time to render an image	0 - 2
Realism	Choice of visualising 3D views	0 - 2
	Realistic representations	0 - 2
	Availably Library objects	0 - 2
	Setting up an image	0 - 2
	Time to render an image	0 - 2
Walkthroughs	Choice of visualising 3D views	0 - 2
	Realistic representations	0 - 2
	Availability of sun locations	0 - 2
	Setting up a walkthrough	0 - 2
	Time to render a walkthrough	0 - 2
Tuition	Helpfulness of free tuitions	0 - 2
	Availability of tuitions on the internet	0 - 2
	Literature provided with the software	0 - 2
	Usability	0 - 2
	Terminology	0 - 2
Time Scale	Length of time to carry out each command	0 - 2
	Length of time to set up cameras	0 - 2
	Length of time to set up a walkthrough	0 - 2
	Length of time to render images	0 - 2
	Length of time to render a walkthrough	0 - 2
Cost	Cost in comparison to 2D uses	0 - 2
	Cost in comparison to 3D uses	0 - 2
	Cost in comparison to modelling time	0 - 2
	Cost in comparison to quality 2D outputs	0 - 2
	Cost in comparison to quality 3D outputs	0 - 2

Table 4.2: Software marking Criteria

Each software package was analysed in accordance with table 4.2 during the process of learning the software and modelling an existing building which will be discussed in section 4.1.3 and 4.1.4. The marking criteria are based on common features available within each software package.

The results are summarised in the following Tables (Table 4.3 to Table 4.7)

AutoCAD

	Comments	Score with a maximum of 10
Ease of use (2D):	Very high quality. Good hatch and block selections. The use of different line types and line weights add to the quality of the finished product. Easy to use and learn, straight forward selection options. More commands than needed but can be hidden from view.	9/10
Ease of use (3D):	When using AutoCAD in 3D, unlike other packages such as ArchiCAD and Revit, all elements needed to be created separately from solid objects. All doors and windows were created separately using a variety of solid objects and extruded polylines, and fitted within the opening, created by subtracting shapes from other shapes. This method is very time consuming	5/10
Print/Plot Setup:	Setting up a drawing onto a paper is very simple, it is possible to use a border template or create your own border. It is possible to view the print in paper view and create accurate scaled drawing, with an option to create coloured prints or black and white (Greyscale or Monochrome) prints.	8/10
Toggle 2D to 3D:	It is simple to toggle between model and paper views, and with the use of the 'Views' toolbar it is simply a matter of selecting the appro priate button for the required view whether 2D or 3D.	7/10
Visualisation:	Brilliant visual qualities. Scaling the used materials caused much problems and made the process longer than needed.	8/10
3D Realism:	Very realistic representation. Shadow s and lighting does not appear as accurate as in other applications.	7/10
Rendering and Walkthroughs:	When creating a rendered image, camera properties cannot be edited, giving only one fixed focused lens.	7/10
Tuition:	The author had previous knowledge of AutoCad, and therefore did not need to consult tuitions even when learning new 3D commands.	5/10
Time Scale:	The time needed to produce this model is higher that the other software as each element needed to be created separately.	5/10
Price:	£3675	8/10

Table 4.3: AutoCAD Review

ArchiCAD

	Comments	Score from 10
Ease of use (2D):	For many ArchiCAD commands there is a temporary command box, which contains the appropriate tools for the procedure being undertaken. These temporary commands, although increasing screen space have a tendency to move around the screen and reside in the most inappropriate locations. When producing a floor slab it is possible, with two easy steps to, automatically position the walls to follow the perimeter of the selected floor slab. Drawing curved walls and other elements is a very quick and easy procedure.	7/10
Ease of use (3D):	There are a wide variety of wall structures, roof trusses, doors and windows. ArchiCAD can detect possible collision errors. Terrains are difficult to create and needed to be done in small sections.	8/10
Print/Plot Setup:	The 2D quality of ArchiCAD 7 and 8 are poor. It is possible to create drawings and documentation such as window and door schedules, "simultaneously in the same environment-- without any extra effort" [Bullain, 2004]. The automatic generation of all needed 2D and 3D views and schedules is a powerful and highly practical element within the software allowing for a smother and easier use [Khemlani, 2004].	7/10
Toggle 2D to 3D:	Toggling between 2D and 3D is a very simple procedure, and is done by selecting the 3D view button where it is possible to Zoom, Rotate and Pan..	9/10
Tutorials:	Tuitions were helpful but many commands where not fully explained and took longer than first anticipated.	5/10
Visualisation:	The ability to use digital imagery within the model adds to the realism of the visualisations. Mapping the digitally captured images to the model is a very time consuming process with regards to the scale of the inserted drawing, there is no scale to fit option and it is not possible to manually move the image to the correct location within an object. It is possible however to set the materials starting point and orientation so that the correct positioning of the material can be achieved.	
3D Realism:	To enhance the realism of the rendered model it is possible to set the correct location, i.e the UK, set the correct time, insert a background images and add atmospheric effects such as fog.	7/10
Rendering and Walkthroughs:	The rendering procedure is simple, allowing the user to import any image, whether stored in the packages' library, or captured with the use of a digital camera, although accurate scale is difficult to achieve. Within ArchiCAD it is possible to create an accurate 'Sun Study' which can be viewed from any angle within the model. The purpose of such studies is that it illustrates shadow impact by surrounding buildings, and how the shadow cast by the new building will influence the surrounding area. With regards to the interior view, the sun study allows the observation the natural penetration of light during the different seasons. "These studies can also define and verify your passive solar design long before you have the opportunity to build it" [Ameringer, 2005].	7/10
Time Scale:	This model took slightly longer to produce than the other software due to the problems of scaling the materials. The software would benefit from a more visual approach where the material could be viewed, attached to the correct object and changed to suite.	5/10
Price:	£3500. Needs development before its worth the cost.	5/10

Table 4.4: ArchiCAD Review

Revit

	Comments	Score from 10
Ease of use (2D):	Revits draughting abilities are very high with definition between wall lines and hatch. The ability to automatically place windows and doors within the walls makes drawing quicker. Walls will automatically change to suit new dimensions, and walls can be locked in place. Temporary dimensions are displayed when drawing, to show lengths and positions before items are placed.	8/10
Ease of use (3D):	Within the 3D window it is possible to move, zoom and rotate, and move object and position other elements. To increase speed a low level of detail (LOD) is used resulting in only the foreground being visible.	8/10
Print/Plot Setup:	Setting up a drawing onto a paper is very simple, it is possible to use a border template, or create your own border. Once set it is simply a matter of choosing the correct image and dragging to the view. The scale and other settings can be changed to suit in the properties toolbar. It is also possible to automatically create Door, window and room schedules. If the model is changed, all schedules will be updated automatically.	8/10
Toggle 2D to 3D:	It is simple to toggle between all views by selecting the correct view from the list.	9/10
Tutorials:	The Tuitions were helpful and made the learning an enjoyable proces s and Lachmi Khemlani [2004], founder and editor of AECbytes would agree.	9/10
Visualisation:	The ability to use digital imagery within the software allows actual images of materials or environments to be used within the model. It is possible to import an image, such as an OS drawing which can be locked and built upon.	7/10
3D Realism:	There is a good Library within Revit which can be updated via the internet so to keep up to date with new products. The biggest advantage to this software is the facility to create Library objects.	5/10
Rendering and Walkthroughs:	In order to aid with realism of rendered images, Accurender developed by Bob McNeel in the US is used [Day, 2001]. The software also offers the use of Pantone colour definitions, in additi on to the 16-million color Windows palette [Day, 2001]. When compared to other software the rendering abilities are poor, shadows appear flat and materials appear too perfect to be real. A lower quality render produces a much more realistic feel. Still images and walkthrough are easy to create once set. However the rendering time for one single image and walk-through is far too high and needs to be reduced.	6/10
Time Scale:	This model took slightly longer to produce due to the fact that so much more can be created, and much more detail can be added.	8/10
Price:	According to the Excitech web site (www.excitech.co.uk) the software retails at a price of £3640	8/10

Table 4.5: Revit Review

3D FloorPlan

	Comments	**Score from 10**
Ease of use (2D):	The 2D tools are very similar to ArchiCAD, in the way that they are used. The 2D quality is of a lesser standard, but considering the price of the software, this is easily justified. Similar to revit, there are temporary dimensions which are extremely helpful when placing objects such as doors and windows.	6/10
Ease of use (3D):	Similar to the upper market software, it is possible to zoom, rotate and move within the 3D window. Again the appearance is not of a high standard, however for such a cheap software this quality is quite high.	5/10
Print/Plot Setup:	Printing quality is very poor. There is no 'Paper space' as in all the other software, and would probably not be considered as a high enough standard for a 'Planning Proposal'.	3/10
Toggle 2D to 3D:	It is easy to toggle between 2D and 3D by just pressing a button at the bottom of the screen.	8/10
Tutorials:	Although there was no need for the author to use the tuitions to learn this software, reading over the tuitions showed that they give a basic outline of how the software works, sufficient enough to learn.	7/10
Visualisation:	The visualisation qualities of this software are very poor. It is possible to import captured images into the software but it is not possible to scale them correctly.	4/10
3D Realism:	There is a good Library within this software, there are not many objects, but the objects available are of a very high quality, and look very realistic and not, as in other software, too geometrical. These objects add to the realism of the building, however the ability to scale materials would enhance the realism much more.	6/10
Rendering and Walkthroughs:	Rendering does not take long but outcome are not of a very high quality. It is not possible to create an animation, and a walkthrough can only be achieved by using the 'feet' symbols within the 3D window.	4/10
Time Scale:	It did not take long to create this building, this however is due to the lack of detailing abilities within the software.	4/10
Price:	Although it is not a brilliant software, for its price it can achieve more than first expected. Its compatibility with other software, especially 3D studio Max makes the software more valuable.	7/10

Table 4.6: 3D FloorPlan Review

3D TurboCAD

	Comments	Score from 10
Ease of use (2D):	The 2D quality of TurboCAD is very similar to AutoCAD, it is possible to use different line weights and line types in order to create a very high quality drawing.	6/10
Easy to use (3D):	It is very difficult to place o bjects in 3D. Within AutoCAD it is possible to move objects in different views, such as front and Left, within TurboCAD this was not possible and as a result it was impossible to create or place windows.	4/10
Print/Plot Setup:	The Print quality again i s quite high. It is possible to preview the print to see before producing the print out.	6/10
Toggle 2D to 3D:	Similar to AutoCAD, toggling between different views is a matter of choosing the appropriate button.	7/10
Tutorials:	The tutorials were confu sing. The author used her knowledge of AutoCAD to use this software.	5/10
Visualisation:	TurboCAD was removed from the Trial due to its lack of modelling abilities, as a result, this was not tested.	
3D Realism:	TurboCAD was removed from the Trial due to its lack of modelling abilities , as a result, this was not tested.	
Rendering and Walkthroughs:	TurboCAD was removed from the Trial due to its lack of modelling abilities , as a result, this was not tested.	
Time Scale:	TurboCAD was removed from the Trial due to its lack of modelling abilities , as a result, this was not tested.	
Price:	£19.99	4/10

Table 4.7: TurboCAD Review

These tables have summarised the author's opinion of the performance of the software mapped against a variety of functions. The length of time to carry out each function varied from each software package. For example, placing a wall using ArchiCAD, Revit and 3D FloorPlan was a simple process of setting the correct properties such as height and thickness and then drawing the walls, where walls built in AutoCAD needed to be drawn as lines and extruded. Regardless of software usability, only a 2 week period was designated for learning the interface to each software package. The results of modelling the subject property in each of the software packages can be seen in Figures 4.4 to 4.9 in Section 4.1.4 of this Chapter.

At this point in the investigation many issues came to the surface for example, the Revit help menu was very straightforward and made the whole learning process easier, smoother and, more importantly, less stressful. The ArchiCAD tuition was more complicated with many vital commands missing resulting in hours of frustration. Within AutoCAD the help menu was difficult to follow, it contains much information on what a command can do, but provided very little help on how the command should be carried out. 3DFloorPlan was straightforward and the tuition did not need to be consulted as the interface was very easy to learn.

Having learnt ArchiCAD first, learning Revit and 3DFloorPlan was made much easier due to the similarity of operations and commands. Having prior knowledge of AutoCAD helped aid with learning TurboCAD. All chosen software products, although slightly different in their outcomes, are very closely connected in the way that commands are activated and syntax and vocabulary used.

When beginning to build the model, it is advisable to start from the bottom up. Within ArchiCAD and Revit this can be achieved by drawing the floor slab, and positioning the walls with the appropriate properties set. Once the floor slab is drawn the walls can automatically be fitted to suit. Within 3DFloorPlan, the walls are selected and drawn first, once the walls are completed the floor slabs and ceiling slabs automatically appear. For software packages such as AutoCAD and TurboCAD, the walls and floor slabs needed to be created using a variety of different sized solid cubes or extruded polylines.

Once the software was learned it was used in order to generate a model of the Crazy Croissant. This Victorian building has very distinguished features. Its many intricate details, and non-standard windows add to the complexity of the building and the modelling techniques adopted. Figure 4.1 to 4.3 are photographic images of the chosen building.

During this process the software was analysed further, giving a more knowledgeable approach to its use for building design. This will be discussed further in section 4.1.3 and 4.1.4.

Fig 4.1: Main Entrance

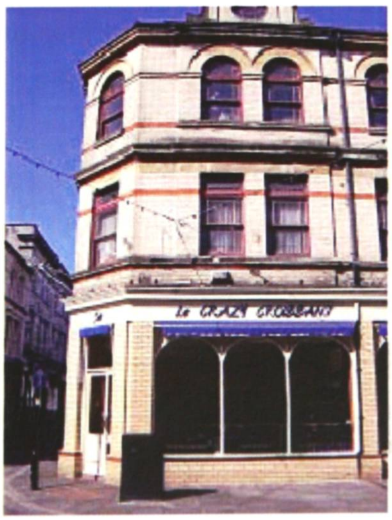

Fig 4.2: Front View

Fig 4.3: Building entrance

4.1.3 Building the Crazy Croissant

The Crazy Croissant building consists of 3 levels, all of which contain non-standard window styles. Once the ground floor had been constructed it was possible to make an exact copy to construct the other levels. When inserting doors and windows, it was hoped that an appropriate style would be present within the ArchiCAD, Revit and 3DFloorPlan Libraries. For most new buildings these libraries are sufficient, however, as Crazy Croissant is an old building, it does not consist of standard door and window patterns, therefore adding such elements proved to be quite a drawn out process, as all windows and doors needed to be created separately and added into the drawing. Within Revit and ArchiCAD this was achieved by using a number of different slabs, solids, and details, which could be saved in a window or door format and then inserted into the models; openings would automatically appear in the wall when being positioned. It was not possible to create extra library items within the 3D FloorPlan, therefore all windows and doors were created using a simple slab representing their shape. It was possible to create extra library parts within AutoCAD to be imported into 3DFloorPlan if desired.

For software such as AutoCAD and TurboCAD, the procedure for creating a door or window is similar, as in both packages, items needed to be created using, and subtracting, solid shapes. As both of the software packages do not hold the 'intelligent' capabilities of the other software packages, when doors and windows were placed into the model openings needed to be created using the Solid 'Subtract' tool. Creating the windows in TurboCAD proved to be almost impossible, slabs would not move and items could not be positioned correctly. As a result of this, TurboCAD was abandoned from the trial.

Once all floors had been created, and all doors and windows had been positioned, all the details could be added. These details included signage, window sills, cornices and architectural details, which are a major feature of the building's character.

4.1.4 Creating Details

Within Revit the detail was created with the use of the modelling toolbar which allowed shapes to be created and moulded around an object. Within ArchiCAD the 'Wall Accessories' tools were used to create a standard shaped cornice, which was placed on the outside of the building, however the cornice kept disappearing and needed to be redrawn several times resulting in time being wasted. Within 3DFloorPlan it proved to be an impossible task ~ resulting in the cornices being represented as a flat object. Within AutoCAD the detailing was made by extruding polylines, which then needed to be joined manually at the corners of the building.

Once the model had been built, it was possible to render each object. As this building is an existing building it was possible to capture digital images of the used materials so that they could be mapped to the model. This task proved to be quite a straightforward procedure within all the tested software, allowing the captured images to be opened as Bitmaps and mapped to objects within the model. Scaling the images however, proved to be a more difficult task throughout, and this was achieved by trial and error. It was not possible to achieve this within 3DFloorPlan, and as a result a very poor representation of the Crazy Croissant was created. To overcome this problem, the 3D FloorPlan model was imported into 3D Studio Max, however, during this process elements of the building were lost, which once again resulted in a poor representation being created.

The results of the trial can be seen below.

Fig 4.4: Crazy Croissant modelled with ArchiCAD

Fig 4.5: Crazy Croissant modelled with AutoCAD

Fig 4.6: Crazy Croissant modelled with AutoCAD and 3D Studio Max

Fig 4.7: Crazy Croissant modelled with Revit

Fig 4.8: Crazy Croissant modelled with 3DFloorPlan

Fig 4.9: Crazy Croissant modelled with 3DFloorPlan and 3DstudioMax

The trial showed that overall, the quality of the finished result for all the software packages was very high, keeping in mind the relative costs. AutoCAD although considered a 2D draughting package by most users, had a very high quality 3D output. However, AutoCAD was very time consuming, the available tuition is not very helpful and therefore patience is needed to learn the product.

ArchiCAD gave a good result. Although the tuition was sometimes unhelpful, and the library too geometrical, the results are still encouraging. Showing clean, bright images, with crisp shadows added to the software's abilities to produce realistic 3D imagery.

Revit was one of the most enjoyable to learn and use, the tuition was easy to follow and the tuitions were much more helpful than those available in the other software packages. The results, although too clean and perfect in the first two images shown above in Figure 4.7, can be set with a lesser quality, as shown in the remaining Revit image in Figure 4.7. The results of a lesser quality render is much more realistic, and faster.

"The availability of cheaper and more user friendly computers and software implies that even small and medium-sized design offices will start using CAAD (Computer Aided Architectural Design)" [Verbeke et al, 2002].

The author had hoped that a lesser priced software would be adequate to allow more building design professionals to progress into 3D, however as Figure 4.8 and 4.9 show above, this was not the case. The results of this trial showed that Revit was the strongest competitor in regards to ease of use, and outcomes. The two lower end software packages, TurboCAD and 3D FloorPlan, unfortunately proved to be unsuitable for creating a realistic model.

Having chosen Revit as the most useful software from the trial to create an existing building, it was then used to model a proposed building using plans and elevations supplied by 'Willdig Lammie', a South Wales (Newport) based architectural company. This building will become the central object of the exhibition and survey which will be described in Chapter 7.

4.2 Modelling a proposed building using Revit.

Section 4.1 of this chapter focused on an analysis of several computer software packages while generating a model of an existing building. This section aims to discuss the methodology used by the author when using Revit, the preferred software package from the trial discussed, to generate a model of the Proposed Building. The decision to do this derived from the desire to test whether the most favoured software from the previous trial was capable of creating accurate models which could be used to present proposed plans during a planning proposal. This trial would inevitably be more challenging as there were no existing materials and no existing 3D views to give a greater understanding of how the building should look when completed. Instead the only information used during this trial were the 2D Plans and Elevations provided by Willdig Lammie.

In 1999 Chen commented that "the creation of urban models remains a great challenge due to its unique property and complexity" [Chen, 1999]. According to Wang et al, [1998] from the School of Planning at the University of Cincinnati, [cited in Zhou et al 2004], there are four geometrical object types. These include "Point objects, which are zero-dimensional objects that have a position but no spatial extension" such as Poles. There are "Line objects, which are one-dimensional objects that are made by connecting two points" such as telephone lines. "Face objects: which are two-dimensional objects with area and perimeter characteristics, such as parking lots and grass fields, etc.; and Body objects, which are three-dimensional objects, such as buildings and barns, etc" [Wang et al, 1998, cited in Zhou et al 2004]. All techniques will be used within the author's model.

The process of producing a computer generated representation of a real life urban scene requires going through many different stages. This is best depicted in Figure 4.10 below, which illustrates the stages adopted by the author when producing the town model that will be discussed in Chapter 6.

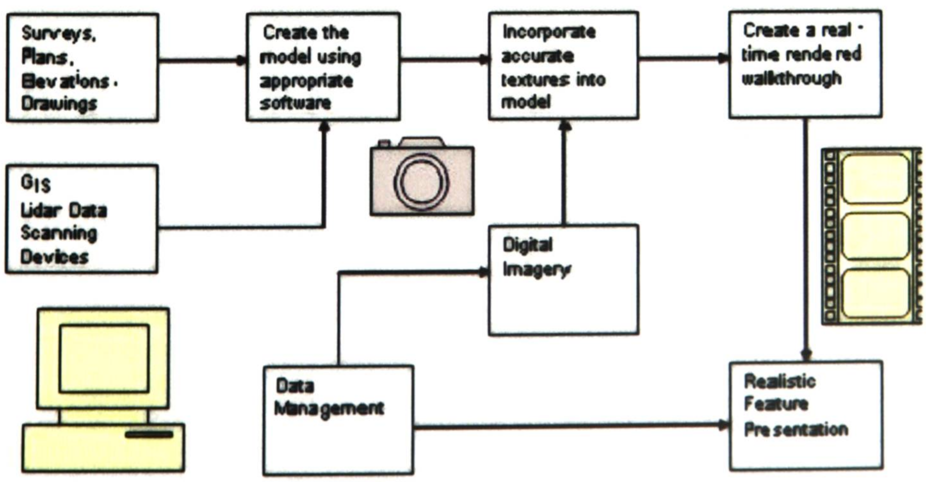

Fig 4.10: Stages of Computer Modelling

As illustrated in Table 4.10 several sources of data were used to create the 3D model of the urban environment which include:

1. Ordnance Survey - With the use of OS plans, it is possible to generate a model from the footprint up. The biggest problem with this approach is that information regarding the building heights and roof types are not included, and must be gathered by a different method.
2. Digital Imagery - Digital imagery is any image taken using digital photography and can include aerial imagery. Digital aerial imagery generally shows roof outline and heights cannot be determined from this technique without the use of photogrammetry.
3. Physical Survey - The method of doing a site survey is the most accurate, but can be very time consuming.
4. GIS/LiDAR Data - GIS LiDAR data and scanning devices can be used to collect height or façade data and is a quick method of gathering a lot of data.

When creating the Urban Environment which will be discussed in Chapter 6 of this thesis, a combination of all four sources discussed above were used, this helped to reduce the time required to construct a basic model, depending on the availability of data. Footprints could be obtained from OS plans, roof outlines were obtained from aerial imagery, and heights were collected on site, or from LiDAR Data. The scale provided within each source may vary, so care must be taken. Other measurements can be taken on site. These methods of data collection will be discussed in more detail in Chapter 5. According to Kerlow [2004] "when creating 3D computer models it is common to use a combination of different software to achieve the desired finish". Beck [2003] agrees, stating that "realistic and completely natural looking terrain databases must be built using real world imagery, aerial photographs or satellite images." This will assist in the realism of the finished model.

Revit was formed in 1997 with an aim to "apply the parametric 3D modelling philosophy of the mechanical design market to that of the 'technologically-backwards' architecture profession" [Day, 2001], and according to the writers of AECbytes in 2001, "It is one of the leading BIM solutions available today". Day [2001] would agree, stating that "Revit comes across as one of the more driven and vocal on its technology and capabilities".

According to AECbyte magazine the "biggest strength of Revit is hands-down ease of use, which is particularly commendable given the complexity of most high-end CAD and BIM packages. The author agrees with this statement and as a result of its ease of use has chosen this software in order to build a Computer Generated Model of a proposed building.

The chosen model for this trial is a proposed office and car park block situated opposite an historical religious building within Pontypridd and in the vicinity of the Crazy Croissant, this will be discussed in Chapter 7, section 7.2.1 of this thesis. As the model was for external viewing only the author used the software to create the outside of the building, leaving the inside of the building empty. This helped to reduce the time required.

The author started the model by first drawing the perimeter of the building. Within Revit, it is possible to change the shape of the wall face, therefore allowing the author to create several hipped roofs which dominate the building design.

With software applications such as AutoCAD, if a wrong wall measurement is created the drawing needs to be changed manually to update the drawing to correspond with the new dimensions. Within Revit, walls will automatically change to suit a new wall size, and can be locked to prevent measurement changing later on in the modelling stage.

Once all the external walls were drawn and edited to suit, the windows and doors were placed. The types of windows and doors used within this building needed to be created separately. Revit allows objects to be created by using the 'Create' function within the modelling toolbar. The 'Create' function makes it possible for the user to create unique Library parts, such as; Doors, Windows, Walls, Columns, Furniture, Lighting Features, and many other elements needed when building architectural models. Once the doors and windows were created, they were inserted into their correct location within the model.

The ability to use digital imagery within the software allows images to be taken of the exact environment and used as a display within the model. This can be very important when trying to achieve a model resembling an actual environment. The author used this function to map an image of the opposite view to each window, giving an impression of reflection, which added to the overall realism of the model.

As the model was of a proposed building, before the textures could be added into the model they first needed to be created, either by capturing digital images of similarly used materials, or within a design package such as Paint Shop. Once the textures and materials had been created, the process of adding these details involved a simple procedure. Once the material had been made, or captured by camera, it was possible to attach the material to an object such as a wall. Each image could be scaled to suit the object and environment, to give a realistic representation of the material used.

A lot of time is required when rendering images, whether still images, or animations. A lower quality render produces a much more realistic feel and reduces the time required. In order to increase speed, a low level of detail (LOD) could be used resulting in only the foreground being visible, therefore the items hidden from view were not rendered until they come into sight. The results of this trial can be seen in Figure 4.11 below, depicting the model of St Catherine's Corner Development.

Fig 4.11: St Catherine's Corner: Front View

4.3 Conclusion

The previous Chapter discussed how BDPs in Wales seem reluctant to adopt 3D technology, chiefly due to reasons of cost and time. This Chapter however has shown, through the use of a small trial, that 3D modelling can be achieved with little cost and less time than actually anticipated. In particular the trial has shown that for those Building Design Professionals who use AutoCAD for 2D outcomes, 3D is attainable at no extra cost, with a little training, and in a relatively short length of time.

However, for those professionals willing to invest in 3D, a series of more powerful tools exist that can enhance quality and improve efficiency. During this trial several CAD software packages were discussed and analysed. ArchiCAD gave a good result, although the tuitions were sometimes unhelpful, and the library too geometrical. Revit was one of the most enjoyable to learn and use, the tuition were easy to follow and the tools available were much more helpful than those available in the other software packages.

As part of this thesis the two models discussed in this chapter will be placed within an urban environment. In regards to the existing building, surveying the area took several hours to ensure that accuracy was achieved, land measurements were also gathered so that the existing building could be placed within a replica of its actual environment.
One method to try and quicken the modelling process is through the techniques used for data collection. There are several different methods available for data collection, some of which may reduce the effort required in the modelling process. As a result the next Chapter will discuss the different techniques available in the hope of finding a faster way of gathering the required data.

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CHAPTER 5: Data Acquisition

"There is a growing demand for three-dimensional (3D) models of Urban environments for many applications, including urban planning, virtual reality and propagation simulation of radio waves for the cell phone industry" [Fruh, 2001]. Currently, the process of generating a realistic urban environment is very time consuming and requires "significant manual intervention" [ibid]. The method used to gather real world data, such as levels, locations and heights, is almost as time consuming than the actual generation of the computer model of the surveyed area. In this chapter contemporary data issues are reviewed.

Current technology for data collection has shown considerable development over the past years with techniques that include aerial and close range photogrammetry, airborne and ground-based laser scanning, and GPS surveying. The current situation is summed up by Billen: "For many years, acquisition techniques and computational processes evolved continually and the practical limitations of the use of 3D information decreased", but "in most of the cases and especially in urban contexts, the evolution to real 3D geo-objects is rather slow" [Billen et al, 2003].

"While current sensing and modelling technologies offer many methods suitable for modelling a single or a small number of objects, an accurate large-scale urban model still remains costly and difficult to produce" [You et al, 2003]. The remainder of this chapter will focus on contemporary methods available for data acquisition of large scale urban environments, and discusses the use of GIS[20] and remote sensing techniques to assist in the process. In the final section, issues relating to do with interoperability between CAD and GIS data are discussed.

Essentially, 3D models can either be derived by extruding 2D data or by acquiring 3D data directly. In the former case, additional data is clearly required to create the model in a third dimension. In both cases, additional data is required to emulate the textures and finishes of the real world.

[20] See glossary

5.1 Acquisition of 3D Models

"The need for virtual 3D city models is rapidly growing for applications like city planning and development, location marketing and tourism, car navigation, disaster management" [Lohr et al, 2004]. "The development of tools for the efficient collection of 3D city models, has been a topic of intense research for the past years" [Haala, 2004], as demonstrated in Chapter 2 of this research.

"With technological developments and rapid shifts in consumer demands and expectations, a wider range of products and services have emerged that are either wholly digital (e.g. websites and on-line GIS) or hybrid (e.g. VR, immersive media, WAP phones)" [MacFarlane et al, 2005]. This increased demand for 3D technology will put a greater demand on the building design profession to use 3D technology to aid in the communication of future plans and developments, however as the previous chapter discussed, at present the evidence shows that 3D technology is not widely used.

It seems from the results of the survey reported in Chapter 3 that for 3D visualization to have a place within Urban Regeneration Projects, the process of data acquisition and modelling must be made simpler and quicker.

However, this process is accelerating and significant progress has been made in recent times including the development of 3D Libraries. For example, in 2005 'Google Earth' was launched, allowing the user to view any location on Earth, though not always in great detail. On January 7th 2007 the Google Earth Blog web site [http://www.gearthblog.com/blog/archives/2007/01/google_releases_new.html] released an article which stated that higher quality 3D Buildings can be viewed, some of which have been photo-textured.

On Monday 6th November 2006 a new online feature from Microsoft Corporation was launched in the U.S. called Virtual Earth. The product will "let people view Web search results and driving directions by zooming virtually around three-dimensional, computer-generated renderings of major U.S. cities... It also can be used to virtually fly over a route after getting driving directions" [Bishop, 2006].
"The feature, Virtual Earth 3D, results from a process that turns aerial photographs into detailed computer models of buildings, streets and terrain. Microsoft picked up the technology through its acquisition of Vexcel Corp. early 2006" [ibid].

This competition between two of the major software houses in the world can only increase the pace at which 3D databases grow: "One advantage, Microsoft says, is that Virtual Earth 3D images are more photorealistic and detailed than those in the Google Earth program" [ibid].

For most practical urban regeneration purposes, however, there is likely to be nothing in the library.

A major problem with modelling the real world is one of size and accuracy. Even with the advances in computer capabilities in recent years, modelling the whole of the world on a 1:1 scale still remains impossible even if desirable. Even the modelling of one city would prove to be an enormous and time consuming task, and would require huge disk capacity and memory in order to run seamlessly and effectively. Reducing the level of detail and polygon reduction can aid with the time process, but may still remain too large for one computer to model and run. One indication of the size of data holding and processing power is that within 2 and a half years of this research a new computer was required to undertake the modelling described here simply because the original was not capable of keeping up the required pace.

Dividing an area into smaller sections can be a way to distribute the model onto different computers, therefore reducing the file size and allowing for the workload to be divided between other members of the workforce. A disadvantage with this proposal is "one of fusing multisource data consistently and accurately" [Ribarsky 2003], not only when joining the completed data but also when insuring that the same high production quality is reproduced throughout the workforce.

There are currently a number of methods that can be used to generate a computer replication of a real life scene, whether urban or otherwise. In an article written by Christian Fruh and Aviden Zakhor [2002], several different methods were discussed. One approach was noted as being "Remote Sensing, where 3D models are created by stereo vision or synthetic aperture radar algorithms, using satellite or aerial images" [Fruh et al, 2002], this is a quicker method but lacks detail and textural information which is vital to the realism of any Computer Generated Model and virtual walkthrough, one of the areas most important to this research. Different methods of data acquisition were also discussed in the article '3D Reality Modelling: Photo-realistic 3D Models of Real

World Scenes, by Sequeira et al [2002], where it was stated that "there are two techniques for 3D reconstruction of real objects and scenes that are commonly used. One is based on active range data (e.g. structured light, laser range finders), and the other is based on video images normally referred as image based modelling."

The following sections will focus on the different methods of data collection. A distinction has been made between Air-borne and Ground-based techniques, though this overlaps somewhat with an alternative distinction, that between remote sensing and interventionist techniques. The term "remote sensing" as well implies acquiring information about an object without physical contact with it, so that for instance any type of photography is a form of remote sensing.

5.2 Ground Based Model Building

Ground based model building involves the process of modelling using ground based data acquisition tools; surveying instruments, cameras and scanners. The methods of gathering data at ground level involve high time input.

Originally these techniques were devoted to the acquisition of 2D or planar data, generating the plans and elevations long associated with development of the physical fabric. The advent of the digital age ushered in CAD in relation to building construction (Chapter 2) and GIS in relation to urban modelling.

"The first GIS were developed in the middle of the 1960's by governmental agencies as a response to a new awareness and urgency in dealing with complex environmental and natural resource issues (Peuquet and Marble, 1990) [Cited in Tanyer et al, 2005]. As the need for 3D information grows, so 3D GIS develops. Industries such as urban regeneration and telecommunication are all benefiting from the developments of GIS capabilities, and "since early 1990 GIS has become a sophisticated system for maintaining and analysing spatial and semantic information on spatial objects" [Stoter et al, 2004].

GIS. has many definitions, Burrough (1986), author of Principles of Geographical Information Systems, defines GIS. as "a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes". Alternatively GIS might be defined as the software, hardware and personnel that allow the integration and analysis of geographic data. In relation to GIS, remote sensing is any technique to collect the data to be used in GIS.

There are numerous uses of GIS, which includes the ability to analyse the effects of different scenarios on surrounding areas such as floods and earthquakes, exploring demographic information of countries around the world, predicting floods and mapping rivers, locating businesses and creating travel routes, and determining visibility (line of sight) of new developments from known locations. Current commercial GIS. packages include, ArcView, ArcGIS, Arc info, MapInfo and Small world. GIS now "plays an integral part in national and local government, military and academic institutions" [Rudiman, 2003].

This data is clearly relevant to the present study.

5.2.1 Mapping Agencies

The most time consuming approach to computer based modelling is to acquire and input all data manually. Data can be obtained from mapping agencies such as Eurographics, or Ordnance Survey (OS) which is described as "the national mapping agency for Great Britain, and one of the world's largest producers of maps which can be found as far back as 1747, when King George II of England commissioned William Roy to create a military survey of the Scottish highlands." Surveys can be purchased from the web page www.ordnancesurvey.co.uk where the drawings are updated as Britain develops (Landline Data is the product that contains building footprints).

The main problem with using OS survey drawings as a footprint to create an urban model is that no 3D feature data exists; there is no height data (except height above sea level), elevation or detail data, and vegetation is represented through symbology. Therefore the OS drawings can really only be used to determine the perimeter of each building, and its location.

5.2.2 Cameras and Scanning Devices

"Photorealistic visualisations of building façades require the availability of texture from terrestrial images" [Haala 2004]. To ensure realism, a digital camera can be used so that the images of the façades, landscape, backgrounds and materials used in the construction of the building can be accurately captured and mapped to areas within the Computer Generated Model.

"Terrestrial, or ground-level, images are the most convenient data sources. Although this data provides high fidelity ground, vegetation, and building façades detail, it lacks building top information, and occlusion limits its range" [Hu et al, 2003].

Panoramic images are convenient data sources taken with "cameras with special lenses or mirror systems to acquire the images" [ibid], and an "image processing software stitches them together from multiple planar projection images" [ibid].

In 2002 researchers Szymon Rusinkiewicz from Princeton and Olaf Hall-Holt Marc Levoy from Stanford University published a paper describing the use of a 3D range scanner to obtain a full 3D image of a small handheld objects by holding and rotating them in front of the scanner. The outcome captured small details and unevenness in the models surface which, as a result created a highly detailed and accurate model. Data acquired through the scanning process, although detailed in its modelling can only be gathered one object, building or one street at a time.

Gaining data of smaller objects in a laboratory with all sides easily accessible is much easier than gaining information of larger objects such as buildings, where views can be restricted by other objects such as traffic, and trees. Unlike in a laboratory the environment in which the data needs to be collected is harder to control, the building cannot be moved and lighting cannot be regulated to the same requirement throughout the day. Reflective materials such as glass can also prove to be problematic when scanning.

Researchers Fruh et al [2001], Sequeira et al [2002] and Singh [2003] have all looked at data acquisition that involves the use of cameras and scanning devices, attached to a vehicle and driven through streets in order to create a realistic representation of an urban scene. Such use of digital imagery adds relatively high quality images to the scanned buildings. This method is called Laser light (Light Amplification by Stimulated Emission of Radiation). "The camera captures images for textures, the horizontal laser scanner tracks the truck's motion, and the vertical scanner captures 3D building facade data" [Hu et al, 2003].

Gary Singh [2003] in his article 'Modelling Cities One segment at a time' referred to the research carried out by Ioannis Stamos from the School of Robotics at Columbia University. "Stamos used a Cyrax laser range-scanner to acquire 3D range scans of large-scale urban scenes" [Singh, 2003]. It was noted that the Cyrax 3D scanner is a portable laser scanning device that "captures, visualizes and models complex structures and sites with an unprecedented combination of completeness, speed, accuracy, and safety" [Allen et al, 2003]. It works by pointing the scanner towards the scene and the system then emits a laser that scans the scene and records the coordinate of the first feature that the laser intercepts. The data gathered by the scanner can be used in a computer package called 'Cyra's[21] Cyclone', which allows the user to export the data to CAD and rendering packages [ibid].

During a demonstration of scanning technology by Dr David Kidner at the University of Glamorgan the author was given opportunity to see how this technology worked, and what the results were. The scanner system included a Scan Head, Tribrach, Tripod, Ethernet cable and power cables, 2 Batteries and a Laptop.

The first stage was to set up the Scanner. The scanner is set onto a tripod which is levelled by the Tribach, the Laptop is connected to the scanner through the use of the Ethernet cable. Once setup the power supply can be connected.

The Laptop is used as a means to store the data, this is done through the Cyclone software. Once loaded and a new database created, the scanner can be started and all collected data is stored within the Cyclone database on the Laptop.

When creating a complete model, such as a building, the tripod will need to be repositioned, and several scans conducted (the process of triangulation) to create an accurate model. Targets need to be used so that the data can be connected correctly.

During the scanning procedure the built in camera captures an image of the building.

[21] Cyrax has been bought by Leica.

The results of this scan can be seen in Figure 5.1 below.

Fig 5.1: Scanner Image of an area within the University of Glamorgan

It was suggested by Singh [2003] that "urban planning, architecture, construction, entertainment (cinematogrophy and games), archaeology, and disaster recovery are all disciplines that his research could affect" [Singh, 2003].

The 3D scanner works with the use of two rotating mirrors, resulting in the beams being deflected in two different directions. A 2D scanner, such as those used in homes and offices only have one rotating mirror which passes along the scanned image in an orthogonal plane. 3D laser scanners can be obtained from companies such as MENSI, which was founded in Paris, France in 1987 by Auguste D'Aligny and Michel Paramythioti. Mensi (Alpharetta, USA) uses 3Dipsos system to reconstruct 3D models. Examples of work generated by Mensi can be seen on their web site http://www.mensi.Com/Website2002/image_gs.asp. Other industries such as 'Aprservices' (London), will carry out the scanning process for the clients, such as an Architect or Landscape Designer.

"One general problem for the provision of façade texture from terrestrial images is the large amount of terrestrial scenes to be processed" [Haala, 2004]. Obtaining data through the scanning process provides acceptable accuracy but where there is a lot of signage, lampposts and trees the images will be effected and will require a large amount of human intervention to create an accurate visual of each building.

The following section will look at the different methods of air-borne techniques.

5.3 Air Based Model Building

"Remote sensing represents a major though still under-used source of urban data, providing spatially consistent coverage of large areas with both high geometric detail and high temporal frequency, including historical time series" [Herold et al, 2005], and is the is key to Air-based Modelling.

According to Herold et al [2005], there has been an increase in the availability of Remote Sensing data which is suitable for Urban analysis. They believe that "Remote sensing imagery can greatly enhance the interpretation, visualization and presentation" of a model by providing a recognizable background. Sharing this view, this current research set out to examine the efficacy of remote sensing in 2003.

The Air-based technique of laser scanning was first introduced as a "tool for generating digital terrain models [Kraus and Pfeifer, 1998; Petzold et al., 1999], but soon its use was extended to more complex applications such as vegetation analyses [Hyyppae et al., 2001; Naesset, 2002; Lefsky et al., 2002] and building reconstruction [Haala and Brenner, 1999; Brenner, 2005]" [cited in Wotruba et al, 2005].

"Beyond its primary application for the generation of high quality digital terrain and surface models, airborne laser scanner data has proven to be a rather powerful source for a wide range of 3D GIS object tasks. Among these tasks, the automatic generation of 3D building models as an integral part of 3D city models of topographical databases has found special interest" [Schwalbe et al, 2005].

5.3.1 Aerial Imagery

Aerial images "provide accurate building footprints and roof heights" [Hu et al, 2003]. Although Aerial Imagery is capable of a high quality and resolution, the shadows cast by houses and scenery can make it difficult to pinpoint an exact location. "While you can achieve sub meter resolution with this technique, you can only capture the building roofs and not their façades" [Fruh, 2002].

According to Fruh [2002] creating 3D models with high levels of detail from aerial and ground views "involves an enormous amount of manual work," although this work may be visually pleasing the process is one that requires much time and patience.

Although aerial imagery are 2D still images, advancements in technology has allowed for 3D data to be collected, this is achieved by overlapping several images. This technique is called Photogrammetry.

5.3.2 Photogrammetry

"Photogrammetric techniques use 2D images without any priori 3D data" [Hu et al, 2003], and involves the task of overlapped images, according to Tao [2004] it "is a classic and dominant approach for 3D data acquisition...the most efficient way to collect data is from an airborne platform" especially due to the development in the area of digital imaging technology.

During a demonstration of ISDM[22], organised by the GIS division at the University of Glamorgan, it was possible to see the results achieved by using this method of data collection. The outcomes were disappointing when considering the amount of time required, not only for joining the 2D still images, but also the time needed to create 3D linear models. The results showed only the roof outline, the accuracy of which depended entirely on the user's ability to select the correct points, using specially adapted glasses that allow the viewer to view the images in stereo. These images cannot however be viewed in elevation, only in Plan, though this gives the impression that the buildings are elevated out of the computer screen.

According to Lohr et al [2004] "3D data derived from aerial photogrammetry provides a very high geometric accuracy and also an excellent image resolution," the process however, is very long and requires much patience and a steady hand.

[22] ImageStation Digital Mensuration' (ISDM), a photographical systems computer package.

5.3.3 LiDAR Data

"Light Detection and Ranging (LiDAR) sensing technology evolved in the 1970s for 3D modelling. In the late 1980s, researchers began using the newly developed GPS for accurate aerial positioning. Combining the two systems, GPS and LiDAR, increased the accuracy and lowered the cost of obtaining aerial LiDAR data" [Hu et al, 2003]. A basic LiDAR system comprises of a Laser, INS (Inertial Navigation System) and GPS Global Positioning System. The system is attached to an aircraft and emits laser beams whilst flying over the required area. The time it takes for the laser to hit the ground and return to the aircraft is recorded. Using speed of light calculations the height of the ground or object can be calculated, and millions of data points can be recorded during one flight. "Airborne LIDARs measure 3D points, which are distributed over the terrain surface and on objects rising from the ground like trees or buildings. Even though basic DSM may be sufficient for a number of applications, further interpretation and qualification of the original height data may be necessary" [Lohr et al, 2004].

"A LiDAR sensor system permits an aircraft flyover to quickly collect a height field for a large environment with an accuracy of centimetres" [You et al, 2003] and "due to its advantages as an active technique for reliable 3D determination, LiDAR has become a rather important information source for generating high quality 3D digital surface models" [ibid]. "In urban areas, LiDAR also provides useful approximations for urban features and buildings, and offers "a fast and automatic way to collect height or distance information" [Tao, 2004].

However, "sample-rate limitations and measurement noise obscures small details and occlusions from vegetation and overhangs lead to the data voids in many areas" [You et al, 2003]. For this reason, researchers from the University of Carlifonia, You, Hu, Naumann and Fox, worked towards refining the "acquired models to be geometrically accurate within all local details, rather than in a global average sense" [ibid].

The use of LiDAR data is a very promising technique for data acquisition but still required much development before it can be considered a feasible option for accuracy and detailing. Chapter 6 will show that the use of LiDAR for data acquisition requires a long task of identifying building locations and heights, roof types and orientation. In 2004 the "LIDAR systems allowed a measurement rate of up to 100,000 Laser measurements per second." On-board of a fixed-wing aircraft such a measurement rate provided more than four 3D measurements per m^2. Horizontal accuracy of derived elevation data is typically better than 0.5m, while height accuracy is better than 0.15m. These accuracies meet the LOD-2 requirements for reconstruction of buildings [Lohr et al, 2004]. As technology develops, the accuracy and quality of the collected data will undoubtedly improve.

For the purpose of this research LiDAR data was used to help in the generation of a 3D urban model. In the case of the model generated to aid with this research, the LiDAR data was of such low quality that it was necessary to remove the whole of the Lidar data and replace the buildings and terrain with solid geometrical shapes, this will be discussed in detail in Chapter 6 of this thesis.

During this research a demonstration was given to the author by Anthony Roulier Callaghan, a research student at the University of Glamorgan. Both researchers required the use of LiDAR data for different purposes, Roulier Callaghan explored its uses for researching into the area of airwaves, and how they were affected by surrounding buildings and landscapes, the lack of detail and smoothness of elevated surfaces were not important as the basic outline and roof heights were sufficient. In regards to this research, detail and accuracy was essential.

In 2001, Fruh et al [2001] stated that there had been "a growing demand for three-dimensional (3D) models of Urban environments". If Fruh is correct then there is a basis for the development of a new industry that will spring from a fusion of professions concerned with the development process. These professions have already adapted computer technologies that have become normative within their professions. In earlier chapters the use of CAD by Architects and other BDPs were explored. CAD has been developed for relatively small scale, highly accurate data relating to one or a few new buildings.

This chapter examined the development of GIS. GIS has been developed for relatively small scale, less accurate terrain data. Planners use GIS. According to Tanyer et al, [2005] "Geographical Information Systems (GIS) are one of the important IT tools that have been used in the urban planning process". This observation is consistent with Zhou et al's [2004] opinion that "GIS plays an important role in city planning, communication system design, micro-climate control and simulation, tourism, etc. The demand for visualization of urban models and realistic presentations of the real world has been increased dramatically today".

As 2D CAD morphs into 3D CAD and GIS adds 3D capabilities and techniques, there is clearly a need to examine this fusion. If a building developed in a CAD environment can be placed in a terrain model developed in a GIS environment there must be potential to accelerate the development process.

The following sections will therefore focus on the interoperability between CAD and GIS to generate a 3D urban model, and to investigate whether interoperability can reduce the time of the modelling process.

5.4 Urban Modelling

Today, with the ever growing trend of Television programmes such as 'Time Team' and 'Grand Designs' which showcase the uses of 3D modelling, it is inevitable that this 3D technology will continue to increase in popularity. With regards to TV and Films, the computer industry continues to grow in strength with new computer animated films being released annually contributing to the film industries profit margin. However, in regards to the Building Design industry this technology is less embraced. When this research commenced in 2002, there had been mixed messages regarding the possibilities of generating a realistic model of an urban environment, for example, Chen [1999] believed that urban modelling had become a reality back in 1999 due to advanced developments in computer technology, where two years later Fruh et al [2001] suggested that 3D modelling was still very time consuming (Section 5.3.1).

Chapter 3 established a reluctance to adopt 3D technology on the part of the BDP, the main contribution to this factor being cost and time. However, with the use of developing GIS data, it may be possible to achieve a 3D Computer Generated Model in less time. In 2003, Coors suggested that "there is a strong need for a three-dimensional geographic information system (3D-GIS) to manage 3D geometry and topology, integrate 3D geometry and semantic information, analyze both spatial and topological relationships and visualize the data in a suitable form" [Coors, 2003]. However in order for GIS technology to be useful within the Building profession, file formats that would allow both GIS users and CAD users to merge data, need to be examined.

5.5 CAD and GIS Interoperability

"3D object reconstruction of the real world is a relatively new issue in GIS, since generating 3D models used to be the work of CAD-designers" [Stoter et al, 2004]. According to Tony Flynn, Bentley's chief marketing officer in April 10th 2002, "work flows are interrupted, errors occur and productivity and quality may suffer" when CAD and GIS systems are not integrated, and that the interoperability of both software packages, would reduce production time and generate higher quality of work.

From the outset of this research (2002) there was very little literature in regards to CAD and GIS integration, nevertheless for the purpose of this research it was necessary to produce a 3D Computer Generated Model of an urban regeneration project, and to investigate whether GIS data would make the modelling process any quicker. As a result it was necessary to test different CAD and GIS packages to identify whether there was, or could be, interoperability between the two.

With the increased availability of data, it is inevitable that researchers in the built environment would want to incorporate GIS within Computer Aided Architectural Design (CAAD), which would result in a 3D terrain model of an area being generated without the need for a land survey. This led the author to undertake an investigation into the feasibility of using software to develop 3D models.

Although CAD and GIS data are both used to create models of the real world, there are significant differences and qualities between the two software packages in regards to their uses. Reid [2003], described CAD and GIS as being like 'Oil and Water', this comparison was made due to the fact that building design professionals require "high precision placement and accurate measurement, and GIS is neither" [Reid, 2003]. CAD systems such as AutoCAD, generally focus on the 2D and sometimes 3D co-ordinates of an area or building with the use of geometrical objects and mathematical calculations. GIS systems however deal with many different co-ordinate systems, and use points, lines and polygons to generate maps and models and store information relating to topography and built environment, such as their size and location. According to Oosterom [2004], CAD is used to "represents the man-made world" while GIS "captures the natural environment". With the ever increasing availability of GIS data, the author believes that there will be an increase in the demand for CAD and GIS software to merge.

Although the two software types have several differences in how and what they produce, there are also similarities. For example CAD and GIS both deal with geometry, and they both provide representations of the real world. Their integration would result in higher accuracy within Urban Modelling, and would allow building design professionals to design as part of a wider environment, allowing viewers, among other things, to see how an area and surroundings are affected by new designs and developments.

Zlatanova [2004], suggested that building design professionals have been frequently confronted with the request to provide the means to link small scale mapping to newly designed construction models, and the integration of CAD and GIS software could therefore allow users to combine the accuracy, drawing and editing qualities of CAD and integrate them with the spatial analysis abilities of GIS. Indeed, Esri, as a GIS provider, and Bentley, the leading provider of AEC software [McCray, 2004] have already recognised the need for Interoperability and are currently working together to create an "Intelligent integration" [Rudiman, 2003] between desktop and server based products. According to Bacharach[23] [2006], "organizations around the world are working together to develop an open standards foundation for CAD/geospatial information integration".

5.6 Testing CAD and GIS Interoperability: Significant manual intervention

In order to combine data from CAD and GIS sources, it was firstly necessary to examine the file formats and data transfers between standard commercial software packages.

The CAD software provided for this investigation included AutoCAD, ArchiCAD, Revit, TurboCAD, 3DFloor Plan, 3D Studio Max and G Max. The GIS software used were ArcGIS 9 and ERDAS Imagine 8.7. To commence the experimentation the author made a list of the available file formats within each software package, in order to pinpoint any similarities between the softwares. This can be seen in Table 5.1 below.

[23] Executive Director, Outreach and Community Adoption Open Geospatial Consortium, Inc.

AutoCAD	ArchiCAD	Revit	TurboCAD	3DFloorPlan	3D Studio Max	G Max		ArcGIS Inc ArcMap ArcCat ArcScene	ERDAS
3DS	BMP	BMP	3DS	BMF	MAX	GMAX		ArcMAP Doc	aol
BMP	DGN	DWG04	DGN	DXF	3DS	P3D		ArcMAP temp	C.img
DWG	DWG	DWG00	DWG	VRML	AI			ArcSCENE Doc	ALL Raster Ext
DWS	EMF	DGN	DXF		ASE (ASCII)			AI	OVR
DWT	GDL	DXF04	TCT		ATR			BMP	Arc Cat
DXF	GIFF	DXF00	TCW		BLK			DBF	BIL
DXX	MDE	JPEG	TCW 6.5		CHR			DXF	BIP
EPS	PMK	Microstation DGN			DF			DWG	BSQ
JGS	PNG	RVT			DWG			EPS	GDB
JPEG	TIFF	RFA			DXF			EMF	BMP
PCX	MWMF	RTE			FBX			GIFF	DT1
PNG		SAT			IGE, IGS			JPEG	HDR
RLC					LAY			LYR	N1
TGA					LP			PMF	EOS HDF
TIFF					LS			PDF	ERS
SAT					SHP			PNG	GIS
STL					STL			SHP	IAN
WMF					VW			SVG	1A
					WRL, WRZ (VRML)			TIFF	FIT
									GIF
									GLT
									GRRID
									STK
									MDL
									GMD

Table 5.1: Software file format

Although table 5.1 above shows that there are common file formats between the software packages, further investigation showed that not all file formats resulted in a 3D model, and instead the shared results showed a 2D outcome, which could not be used within a 3D Computer Generated Model.

The investigation which tested the compatibility of the software listed in table 5.1 above was carried out in 2002 and re-tested in 2006 with newer software packages: AutoCAD 2007, ArchiCAD 9 and Revit 9.1 but no different outcome. The investigation comprised of a simple 3D model of a house being built within each CAD software, and saved in the file formats highlighted in table 5.1. Once saved the model was opened in the GIS software.

The results showed that, although there are several compatible file formats, when the model was opened in GIS, it did not contain 3D data, and the model could only be seen as a 2D image, which is shown in Figure 5.2 and 5.3. Figure 5.4 shows the results of opening the model in ArcCatalogue, having been saved as a

DWG and DXF file in TurboCAD, although the model is opened in 3D all the coordinates were lost, which resulted in the roof repositioning at ground level.

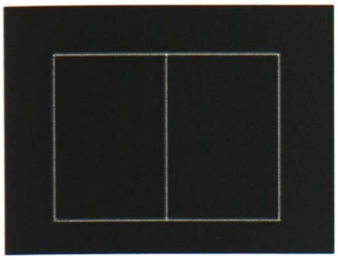

Fig 5.2: Bmp in ArcScene

Fig 5.3: Dwg in ArcCatalogue

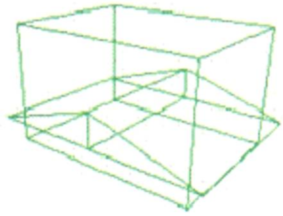

Fig 5.4: Dwg, Dxf and DNG in ArcCatalogue

3D Floor Plan and 3D Studio Max were the only two packages from the software tested that resulted in a 3D model being displayed. 3D FloorPlan was an add-on package supplied with TurboCAD, which was purchased from 'Games Group Ltd' for only £19.99. The results can be seen in Figure 5.5 and 5.6 below.

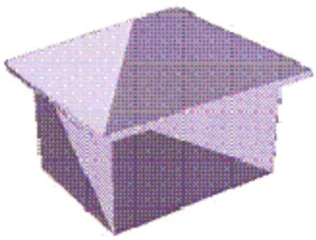

Figure 5.5: DXF 3D Polygone opened into ArcScene

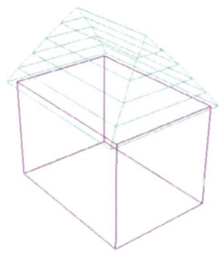

Figure 5.6: DXF and DWG 3D within ArcScene

5.6.1 Testing GIS and CAD Interoperability

Once this test was conducted, it was reversed. The first half of the test concentrated on whether CAD data could be opened and used within GIS. The second half investigated whether a GIS model could be opened within the CAD software.

In order to carry out this investigation a small section of terrain was selected and saved/exported from the GIS software. Once saved and exported using the highlighted file formats listed in Table 5.1, the author tested whether it could be opened/imported into the CAD software.

Once again the results of this investigation showed that it was possible to open some GIS files within a CAD package but, as shown in Figure 5.7 and 5.8 below, only as a 2D image.

Fig 5.7: Bmp, Jpeg, Tiff, Png, in AutoCAD

Fig 5.8: Perspective view: No 3D properties

However, similar to the first half of this investigation, it showed that once again 3D Studio Max was compatible with the GIS data and as a result a 3D terrain model was opened from a VRML file format saved within ArcScene.

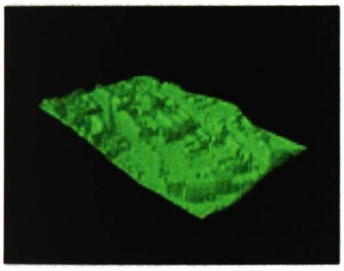

Fig 5.9: ArcScene Terrain opened in 3D Studio Max

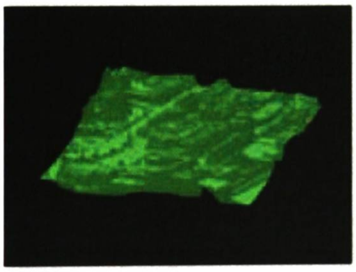

Fig 5.10: ArcScene Terrain opened in 3D Studio Max

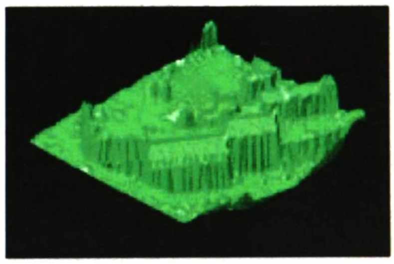

Fig 5.11: ArcScene Terrain opened in AutoCAD

5.7 Conclusion

This chapter has outlined the different technology available for data collection, which has shown considerable development over the past years with many more techniques involving Airborne and Ground-Based methods being developed.

There are currently a number of methods that can be used to generate a computer replication of a real life scene, whether urban or otherwise. The advancement in GIS technology today has provided opportunities for larger areas to be displayed, and a large amount of data to be collected.

To date there does not seem to be any quick, yet accurate form of 3D data collection technique available. While nothing is more accurate than carrying out an on-site survey, the techniques discussed in this chapter for data acquisition are developing rapidly.

In 1999 Chen stated that "Urban modelling has become a reality...due to advanced developments in computer technology" [Chen, 1999]. It is, however, the authors' belief that in order for 3D modelling and VR technology to become a more feasible option within the building and planning profession then the method of collecting data and generating a model needs to be quicker. It is believed that with advancements in LiDAR data the process of data collection can be dramatically reduced, however methods of LiDAR collection appears to be a promising method to quickly gather a large amount of data that can be easily inputted into a GIS computer system, therefore interoperability between CAD and GIS is an important aspect of urban modelling, as collected data can be shared.
As a result, the following section discussed a trial which was conducted in order to establish whether there is interoperability between CAD and GIS data, which would result in an accurate CAD model being placed within the terrain data supplied by GIS technology, allowing the viewer to see the effects of a new development on the actual environment.

The results showed that, although there are several compatible file formats, when the model was opened in GIS or CAD no 3D data was displayed, and the model could only be seen as a 2D image. However, the trial also showed that 3D Floor Plan and 3D Studio Max were the only two packages from the software tested, that resulted in a 3D model being displayed.

Now that there is a possibility of opening the GIS data within 3D Studio Max it is possible to export the model as a dwg or dxf file, which could then be opened in AutoCAD and other CAD software packages.

This chapter has therefore shown, that through the discussed process, there is a possibility of combining CAD and GIS data, which may help to reduce the modelling process by eliminating the need to carry out a survey.

To investigate the use of GIS and CAD interoperability further, the following Chapter will discuss how LiDAR Data and CAD software; 3D Studio Max and AutoCAD, were used to model an urban environment.

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Chapter 6: Modelling an Urban Environment

There are many reasons why a 3D model of an urban environment may be beneficial. These reasons are diverse and include; emergency situation simulations, navigation planning, design, marketing and even presenting future development proposals to clients and members of the general public.

In the year 2000, Bhunu et al stated that "the software currently available is not suitable for design and planning at an urban scale". Only 2 years on Polleyfeys et al [2002], stated that computer graphics "are so advanced that they allow the user to render complex 3D scenes in real time, which has now created an increase in demand for detailed representations of the existing, and especially the proposed 3D world".

This chapter will therefore explore the possibilities of producing a 3D Computer Generated Model of an urban environment and discusses the methods used when generating a realistic model of a town environment, and how materials from the existing environment may be used in order to create realism within the virtual model. It will also discuss how LiDAR data might be used as a method of introducing real terrain features to virtual designs.

6.1 Modelling Existing Environments

As has been established, with the use of computer design packages, it is possible for building design professionals to "walk" their audiences through a development before it is in existence, giving the viewer a sense of a future environment in which they may be involved. This form of presentation allows the viewer to interact with a scene and become almost immersed in an artificial environment.

In the construction industry, computer visualization can be used to present complicated construction information, such as materials, window styles and types, and structural information, in a way that is recognisable to lay-people. These can be presented as still images or short animations presenting the viewer with an all-over view of the generated model.

Segner et al [1991], in the article, Visualization: The Next Frontier In Computer Usage And Application, written in 1991, stated that due to developments in the area of Visualization, such presentational techniques would be greatly used in the construction industry. Although he was correct in his prediction of computer software developments, the survey carried out as part of this research, previously discussed in Chapter 3 of this thesis, showed that visualization is not as widely used as Segner [1991] may have expected. Rather, the current research confirms Marriott's view [2004] that building professionals have been "slow to adapt to this new technology" [Marriott, 2004]. Three years later, this still proves to be the case, at least in Wales [Rao, 2007]

Nevertheless, "designers have always been engaged in making models and other representations of proposed changes, and of existing conditions before the changes" [Ervin, 2003], whether by producing a hand-made model, or producing artistic impressions. It is the author's opinion that there will be a larger amount of BDPs adopting 3D Computer Generated Modelling in the near future, due to the availability of a wider range of software, and its increasing use in popular culture.

The expectation of realism in a Computer Generated Model is very high due to familiarity with existing surroundings. Ribarsky's comments, quoted earlier, bear repeating at this point, where he predicts an, "exponential explosion in the amount of data available for analysis and exploration. The models will ultimately include buildings and everything associated with the environment, such as trees, shrubs, lampposts, sidewalks, streets, and so on" [Ribarsky, 2003], thus providing the public with a virtual model in which the real world is easily identifiable.

There are many matters to consider when modelling an urban scene. For example, there are many species of trees within one area. Should each tree be modelled separately adding to the realism of the area, or should it merely be a representation of all trees, therefore reducing the time, but also the realism of the model? When unnecessary detail is added, the time is increased, cost is increased and people's expectations are increased above what is required. It is tempting to want to produce a model so realistic that variations between what is real and virtual are difficult to identify. The author, although wanting to produce realism, decided that in order to reduce the amount of 'unimportant' information, keeping in mind the purpose of planning and public participation, that neither street furniture nor pedestrians would be added into the model, and that all trees would be represented by a sphere manipulated into a non-spherical form to represent the uneven structure of a tree's parameters. This therefore reduced the size of the file and also the time for model generation, making the whole modelling process a quicker and more feasible option to BDP's.

Ben Schneiderman [2003], stated that "some designers dream about building interfaces that approach the richness of 3D reality, they believe that the closer an interface resembles the real world, the easier the usage." It is all too easy for a designer to identify with this statement, conscious from practice of a drive to continually improve an image or a walkthrough, to make the crossover from an actual environment to a virtual environment, a smoother and more realistic transformation.

The question that arises here is, how accurate does a model need to be? Does all detail need to be added and how often can geometrical shapes be used to represent features in a model. In Chapter 7 of this thesis an exhibition is discussed which showcases several different methods for presenting proposed developments to the general public. One of these methods included a Virtual Reality Model which showed the main development as a detailed model and all the surrounding buildings as plain white representations. Interestingly, not once during this exhibition did a member of the general public question why all the buildings were not detailed. By reducing the background detail, emphasis is not removed from the main development and viewers can focus on the project at hand.

6.2 Modelling Pontypridd

Chapters 4 and 5 of this thesis discussed the different methods of collecting data that could be used to create a Computer Generated Model of an existing environment and how an existing building was generated within several different software packages. This Chapter aims to take the findings from both chapters in order to create a model of a small town environment.

The software used during the modelling of Pontypridd included:

1. ArcMap to Triangulate the acquired LiDAR data
2. ArcScene to export the data into 3D Studio Max
3. 3D Studio Max to create the geometrical shapes to represent the roads, pavments, buildings and landscapes.
4. 3D Studio Max was also used to create the animation.

The model of the Crazy Croissant currently generated in AutoCAD, and the proposed model of St Catherines Corner development created in Revit, were also imported into the finished model. This process will be discussed later.

The first stage of modelling any object, big or small, is to gather the required measurements. Chapter 5 established that there are currently a number of different methods of gathering data and that there is a possibility of CAD and GIS interoperability. Therefore LiDAR data was used in conjunction with OS plans and Aerial imagery in order to obtain terrain data and building heights and locations. The LiDAR data and Aerial images were supplied by Dr David Kidner of the GIS Research Unit at the University of Glamorgan. OS plans were obtained from Digimap™. In order to add realism to the model it was possible to capture digital pictures from the actual environment and use them within the Computer Generated Models through the mapping tool available within 3D Studio Max.

The process of gathering the required data on site would have taken several weeks, the use of the LiDAR data took several hours, although its interpretation was not a straightforward task, and Aerial imagery was needed to identify objects in the LiDAR data.

6.2.1 Creating the Terrain

The LiDAR data was obtained in a .txt format. Using ArcView it was possible to import the .txt file by setting up the 'extensions menu' within ArcView to allow the importation of text files (see Figure 6.1). This was a simple procedure and as a result a 'Table' file was created within ArcView which displayed all of the XYZ co-ordinates gathered by LiDAR (see Figure 6.2). Returning to the 'View1' screen within ArcView and adding an 'Event Theme' from the 'View' toolbar it was possible to view the '.txt' table in a basic point drawing, where each point is positioned in its exact XYZ location as collected by the LIDAR scanner (see Figure

6.3). In the 'Surface' toolbar within ArcView there is an option to create a 'TIN[24] from features.' This triangulated the points to create a solid surface that could later be viewed in 3D viewer (see Figure 6.4), or, in this instance, be exported as a 'VRML' file and imported into 3D Studio Max where it was used in conjunction with AutoCAD to produce the 'existing' urban model.

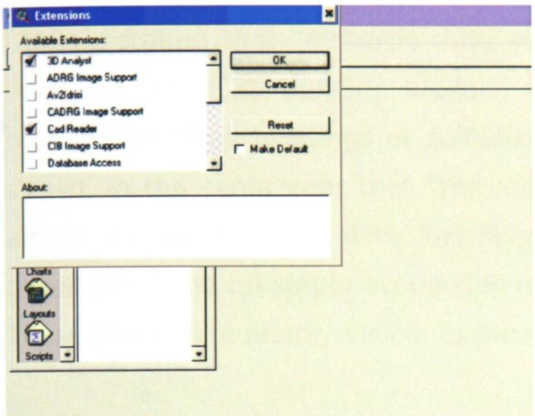

Fig 6.1: Opening .txt file in ArcView

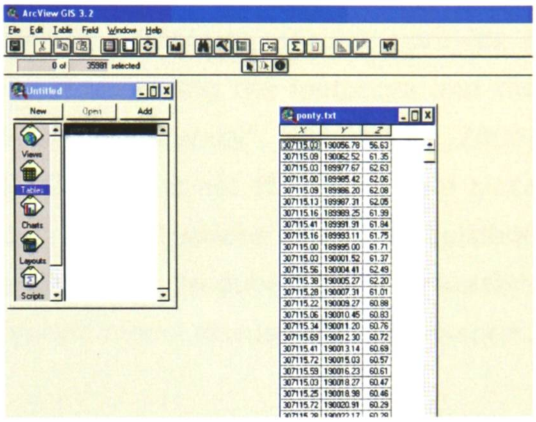

Fig 6.2: Opening .txt file in a Table

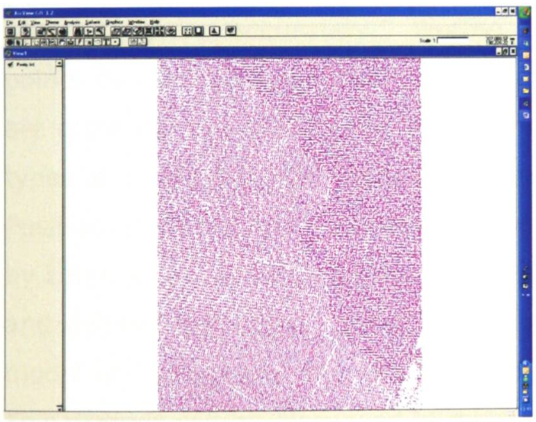

Fig 6.3: Point view within ArcView

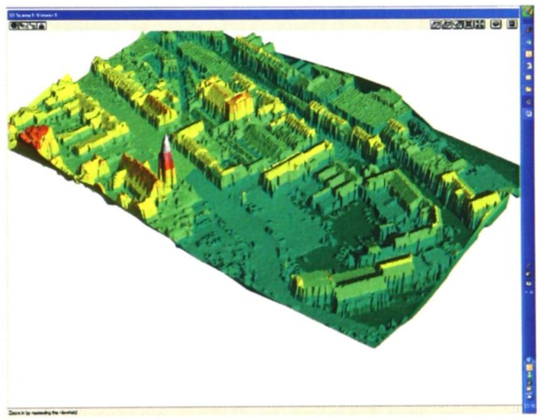

Fig 6.4: 3D View

Earlier Fruh [2002] was cited as saying "while you can achieve sub meter resolution with this technique, you can only capture the building roofs and not their facades". The triangulated terrain model of the data was of very low quality with no clear definition between one building and another. Roofs although straight in reality appeared jagged, there were very few smooth edges, and even roads appeared uneven. The use of LiDAR for data acquisition requires a long task (several days) of identifying building locations and heights, roof types and orientation.

[24] See Glossary

The LiDAR data used for this research was obtained in 2002. At this time the quality of the LiDAR data was very poor, and in the following year Rottensteiner [2003], showed that this situation had not changed, stating that "the resolution of the LiDAR data-which is still below the resolution of aerial images-limits the level of detail of the building models and the accuracy of the positions of the step edges." There were mixed feelings towards LiDAR Data in 2004, with Haala [2004], stating that "Airborne data collection is suitable to efficiently provide a complete set of 3D building models, mainly representing the footprints and the roof shapes of all buildings at sufficient detail and accuracy", though Tao [2004] stated, in the same year that "the modelling aspect is not straightforward since almost all the collected data has holes (due to obstructions or poor acquisition conditions), and no single acquisition mode is likely to produce complete models". These holes were plainly visible in the Pontypridd model discussed in this chapter.

The LiDAR data contained a large amounts of noise, therefore as stated by Tao [2004] the "overall modelling problem is then one of fusing multi-source data consistently and accurately." During a single flight up to "10,000 to 30,000 data points can be captured every second, therefore Errors and artefacts in the data are quite normal and are to be expected" [Leigh et al, 2005]. There are many types of errors that can occur within the data such as Large and Small Blunders[25], Positioning errors and co-ordinate transformation errors, which are a few outlined by Leigh et al [2002]. These errors can be identified within the Raw LiDAR data and deleted manually. However, in order to rectify the errors displayed in the model of Pontypridd, the whole of the data was replaced within 3D Studio Max. This process will be discussed in more detail in Section 6.2.2 of this Chapter.

The images below illustrate the poor level of detail presented in the LiDAR data. The first image (Figure 6.5) shows the extent of the area, where the second image (Figure 6.6) has focused closely on one specific area, and clearly illustrates the level of noise present. The large spear shape to the left of the second image represents a church steeple. The third image, (Figure 6.7) is an aerial image of the town.

[25] See Glossary

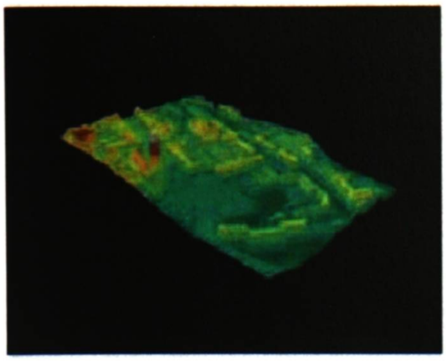

Fig 6.5: The Urban Area of Pontypridd

Fig 6.6: St Catherines Church, Pontypridd

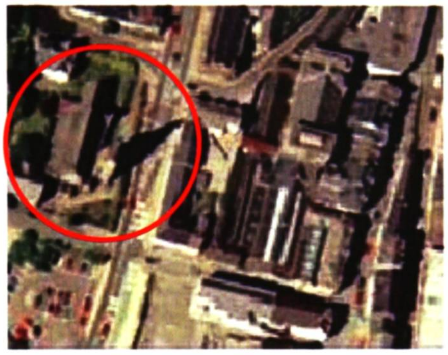

Fig 6.7: Aerial Image of Pontypridd

When examining the data, it was found that several areas were not clearly captured, these areas mainly reflected sudden changes in levels such as the wall surrounding St Catherines church, one of the main areas in regards to the authors research, and other ambiguities included missing buildings and elevated sections where nothing stood. There were also no visible pavements detectable within the LiDAR data, and therefore they needed to be located with the use of OS Plans and Aerial Imagery, which also aided with the identification of buildings, trees, and landmarks.

Due to the amount of noise and lack of smooth surfaces, this data could only be used for the detection of building outlines and roofs, and as a result all buildings were replaced as discussed in Section 6.2.2 below.

6.2.2 Removing and Replacing buildings

By importing the LiDAR data into 3D Studio Max it was possible to identify any errors within the data by zooming in and searching all areas of the modelled data. GIS software such as ArcView allows the data to be viewed in a table format where variations in the data co-ordinates can be identified. However by importing the triangulated model into 3D Studio Max, it was possible to remove existing buildings by using the edit mesh tools available, the removed data could then be replaced by smoother geometrical shapes used to represent each of the buildings shell.

The images below illustrate the process of removing the buildings and demonstrates how the LiDAR data was used in order to judge the location of building perimeters and heights.

The first image (Fig 6.8) shows the LiDAR data of St Catherine's Church. Figure 6.9 shows an outline of the building which has been drawn around the LiDAR data. This outline was achieved by using the LiDAR data in conjunction with OS plans, Aerial images and Digital pictures of the elevated views, this helped to ensure that a more accurate representation was produced. Figure 6.10 shows how, within 3D Studio Max, it was possible to create solid objects, such as rectangles and triangles to create a solid form which represented the external shapes of St Catherines Church. In Figure 6.11 the original LiDAR data has been deleted using the edit mesh tool available within 3D Studio Max.

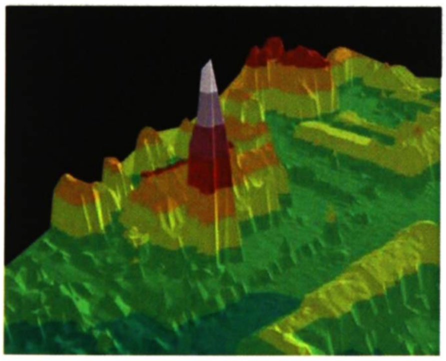

Fig 6.8:LiDAR Data of St Catherin's Church

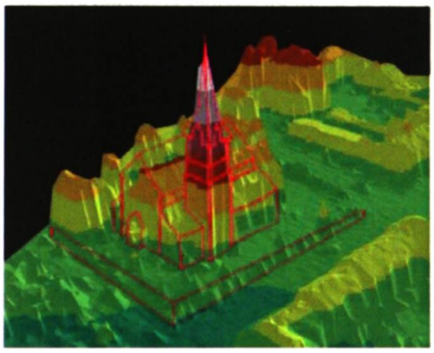

Fig 6.9:Outline of St Catherin's Church

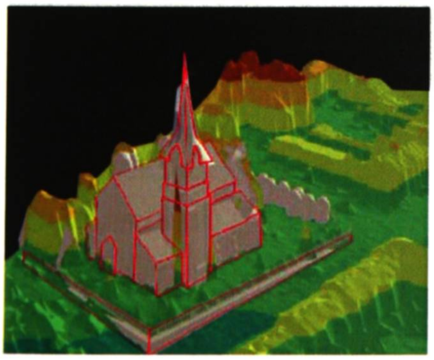

Fig 6.10: CAD and LiDAR of St Catherine's Church

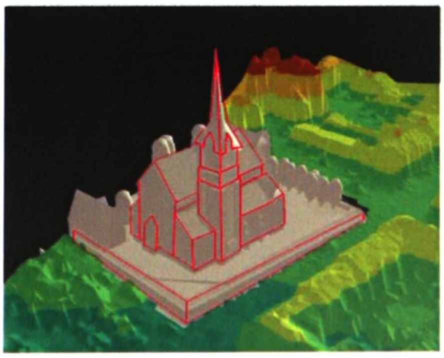

Fig 6.11: LiDAR Data Removing

This process was followed for every building within the LiDAR Data. This can be seen from the three images below. The first image (Figure 6.12) shows the aerial view of the whole data. In figure 6.13 the LiDAR buildings have been removed, and replaced with CAD models following the procedure discussed above. Figure 6.14 is a perspective view of the same model which has been rotated within 3D Studio Max before being rendered. The circle shows the church which was shown previously in Figure 6.6.

Fig 6.12: Plan view of LiDAR Data

Fig 6.13: Same view geometry

Fig 6.14: Perspective view

According to Lohr [2004] "A high percentage of buildings can be modelled using a small number of building primitives like flat boxes, boxes with saddleback and hipped roofs and other geometric primitives like cylinders and cones". This method has been used during the modelling of Pontypridd as it is quicker, and all buildings that are not the main focus of development can be modelled in this manner. For those buildings which needed to be more detailed in order to add realism to the model, digital still images were collected of the building and mapped to the computer model, which helped to add realism to the final model. This will be discussed in section 6.2.3 below.

6.2.3 Adding Texture

The biggest advantage of producing an urban model is that "it takes reality as the base of modelling" [Sequeira et all, 2002]. When modelling an existing environment it is less time consuming to use the acquired digital images and map them to the appropriate area in the modelled scene. This will also enhance the realism of the overall model.

When St Catherine's church was modelled, as it is currently an existing building, it was possible to use 'texture mapping' which is the method of "mapping digital imagery on to a geometric form such as a building face" [Zlantanova et al, 2000]. This will add a higher level of realism to the model as actual imagery from reality is being used.

Below are several images, the first image (Figure 6.15) was discussed in section 6.2.2 of this chapter which illustrated the process followed when replacing the LiDAR data with a CAD model. Figure 6.16 shows the effect of adding a digital picture of the actual building to the model. Figure 6.17 shows the completed model within the LiDAR terrain.

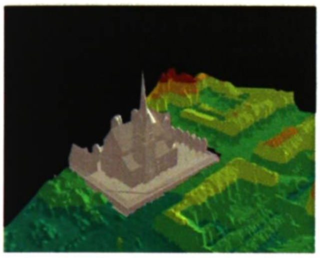

Fig 6.15: Adding Geometry

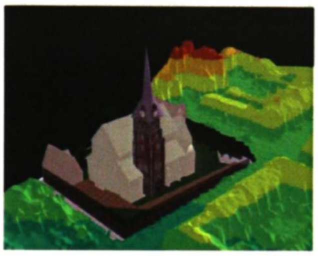

Fig 6.16: Adding Texture

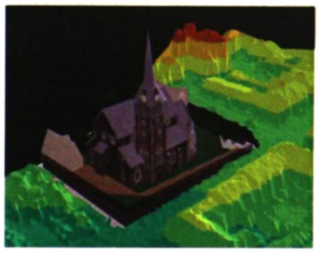

Fig 6.17: Finished Model

The process of 'texture mapping' as discussed above, can be a much quicker process than creating each wall separately. If the building is of a more complex shape it may prove to be more difficult and time consuming. To add more detail to the model it is possible to make features like windows separately, so that they are set back from the face of the model to give the impression of depth. For proposed developments this method of generation is not an option ~ the buildings not currently existing!

For the purpose of urban regeneration where a building is demolished and replaced with a new development, it is possible to build the model in an architectural package suitable for producing scaled models of existing or proposed structures, as discussed in Chapter 4, Section 4.2 of this thesis. Textures for creating realism could be gathered from brochures and catalogues of the chosen materials and used within the computer package to add realism to the model. This form of modelling is very accurate and more depth can be seen within the model. However, if all the buildings within the urban model were created in this way, although it would be very accurate in its measurements and appearance, it would be very time consuming and highly dependant on human input.

Once the buildings had been completed and placed into their correct location, an Aerial image was mapped to the remaining data. Figure 6.18 to 6.20 below shows how this data appears once all the buildings have been added, and an Aerial image has been mapped to the terrain.

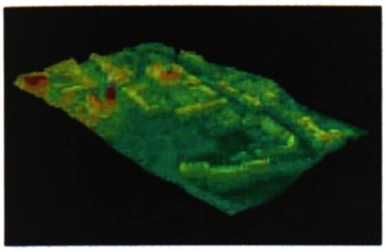

Fig 6.18: LiDAR Data

Fig 6.19: Added Geometry

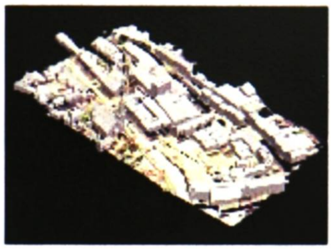

Fig 6.20: Aerial image added

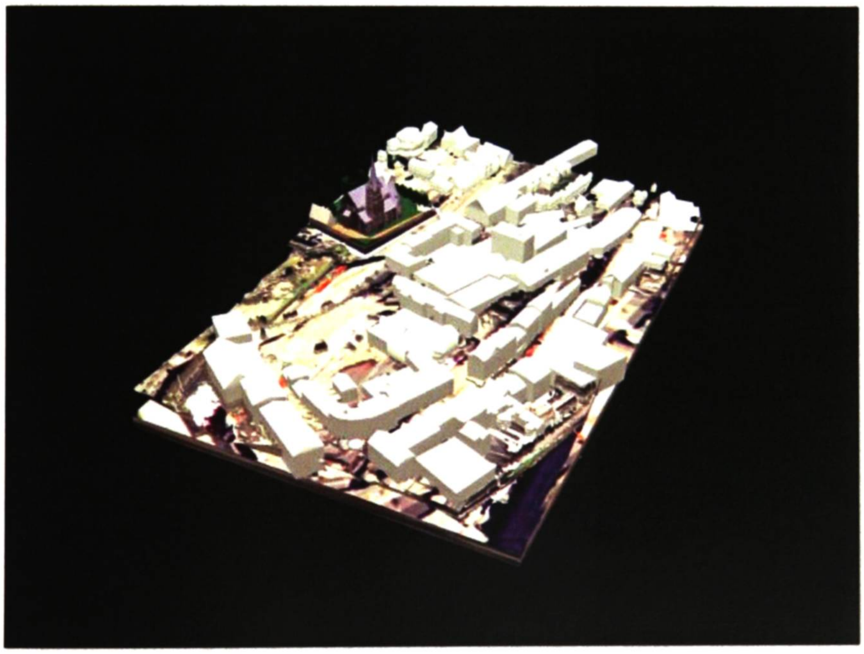

Fig 6.21: St Catherine's Church Added

There is no noise visible within Figure 6.21 at this viewing distance, but this model will be used in order to illustrate a path taken by a pedestrian at a much closer viewing distance, for this purpose a virtual camera will need to be positioned into the model and placed no higher than 1700mm above the model's surface. Figure 6.22 below shows the effect this has on the overall realism of the model due to the noise in the LiDAR data. The raised areas visible within the model could be as a result of cars and pedestrians being present in the Pontypridd area when the LiDAR Data was being collected.

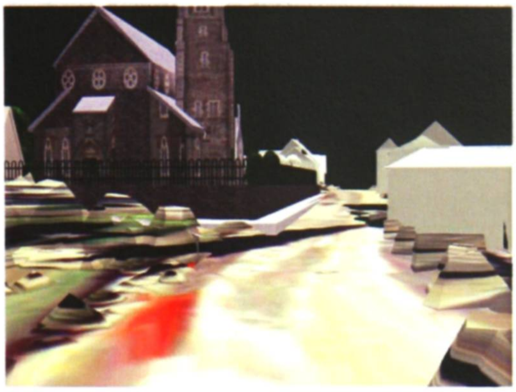

Fig 6.22: A pedestrian View

The results of doing this showed that when viewing the data from a distance the image appeared smoother and more realistic, however when focusing more closely and creating a view from a pedestrians eye level, the unevenness of the remaining LiDAR Data proved to be unrealistic and inappropriate, and for this reason the author decided that the whole data would need to be replaced, and not only the buildings and other landmarks.

Replacing the Terrain data was done following the same procedure as that used for replacing the buildings. Roads were constructed using OS plans to trace the outlines, and the LiDAR Data to place the 'Z' co-ordinates. The end result can be seen in figure 6.23 below.

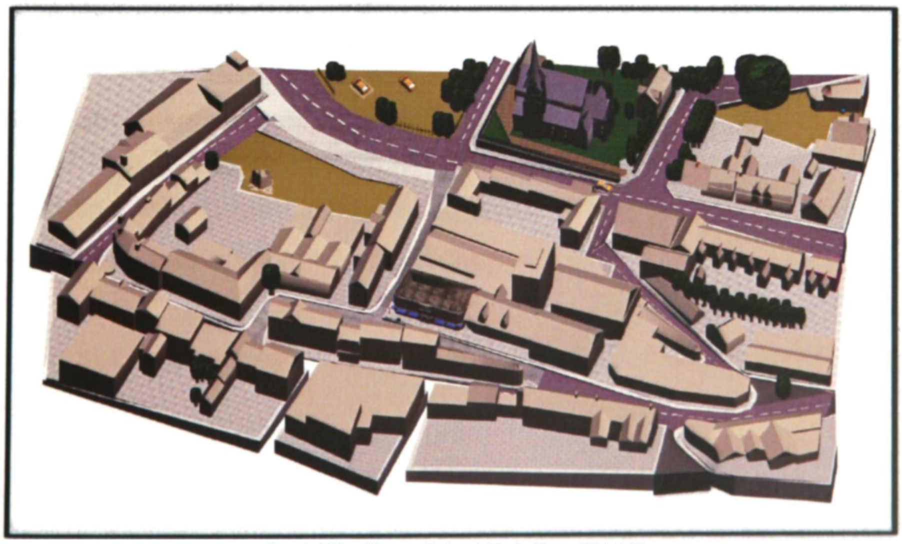

Fig 6.23: Completed Existing Model

The overall results of using the LiDAR data proved to be very disappointing. Although the method of collecting the data was very quick, the quality of the data, with its uneven surfaces, the lack of pavements and several missing object, proved to be unusable within the model.

The accuracy of the data is also considerably less than 100%. Figure 6.24 below shows that there is a 0.5m difference between the top of the Church steeple in reality, and that present in the LiDAR Data.

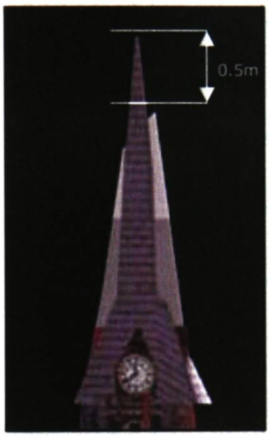

Fig 6.24: Data accuracy

However its use served an important purpose, through identifying the average 'Z' co-ordinates it was possible to use the LiDAR data as a footprint upon which all roads, pavements, buildings and foliage could be placed. Without this data, all measurements would have needed to be collected via a land survey which would have lengthened the modelling process.

6.3 Adding Building Models to the Terrain Model

Chapter 4 of this thesis discussed the development of two models, one of an existing building, the Crazy Croissant, and one of the Proposed building which is to be built on the land adjacent to St Catherine's Church.

The existing building model was created in AutoCAD, the proposed building was created in Revit.

As previously discussed, Revit is not compatible with LiDAR data, therefore before the terrain could be used within Revit, it was imported and edited in 3D Studio

Max, as discussed above, and then exported as a 'dxf' or a 'dwg' file. The results of which can be seen in Figure 6.25 below.

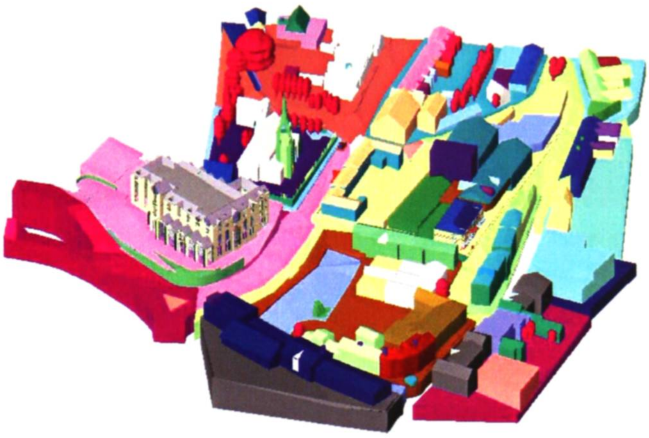

Fig 6.25: View of Pontypridd and the new development in Revit

Once the terrain file was imported into Revit, it became one entity which could not be edited, this made it difficult to add, or remove unwanted data which may, or may not be needed within the completed model. As a result, the Revit model of the Proposed development discussed in Chapter 4, Section 4.2 of this thesis, was imported into 3D studio Max where the Pontypridd terrain data had already been edited.

When importing the two models, (The Crazy Croissant and St Catherine's Corner development), into the terrain data discussed in this chapter, all co-ordinates were lost and as a result both buildings needed to be positioned according to the height and location of the buildings within the LiDAR Data. This was a lengthy process as the position of the proposed building is vital to the accuracy of the appearance of the new development, and could be seen as being biased or deceptive if accuracy was not achieved.

The results achieved by importing the Revit model into the 3D studio Max terrain can be seen in Figure 6.26 and 6.27 below.

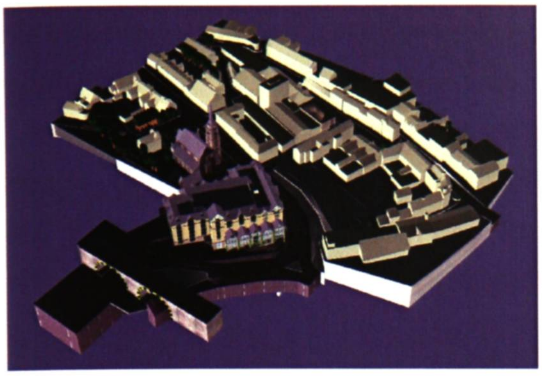

Fig 6.26: Proposed Model from Revit

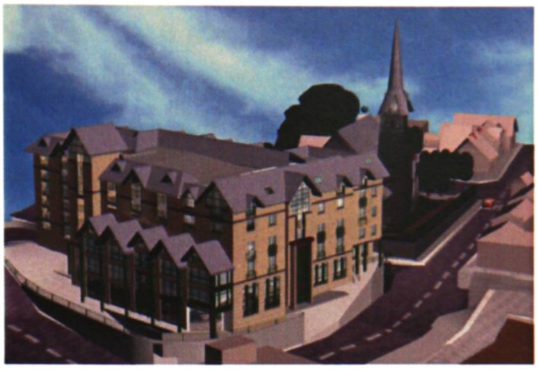

Fig 6.27: Proposed development

Now that the model is completed the final stage is to produce the animation. This was created by placing a 'Virtual' camera within the model as noted earlier. It was placed at the average height of a person, which is around 1.7 meters, and attached to a path drawn within the model; during the animation the camera will follow the set path. Once the model is created an animation is just a matter of placing a camera, setting it on a path and waiting for the computer to create the animation, which may take several hours.

6.4 Conclusion

With the use of computer design packages, it is possible for building design professionals to "walk" their audience through a development before it has been built.

This Chapter has explored the possibilities of producing a 3D Computer Generated Model of an urban environment using a combination of GIS and CAD data, and software, and discussed the methodology adopted. Workarounds like this are more or less transitory as the software suppliers continually update products. However the methodological approach is more permanent: examine software, examine transferability of file formats and interoperability, identify potential intermediary software products, and produce method statements.

Once the model of the existing environment was created, both the existing and proposed buildings discussed in Chapter 4 of this thesis were added to the virtual environment which will be used as part of the exhibition and survey which will be discussed in the following Chapter.

This Chapter has shown that, presently, the accuracy and quality of LiDAR Data is insufficient for direct incorporation into 3D models if a reasonable approximation to the real world is required., However, its use served an important purpose through identifying the average 'Z' co-ordinates and roof types. Without this data, all measurements would have needed to be collected via a land survey which would have lengthened the modelling process.

Furthermore this Chapter discussed the methodology used in order to incorporate the existing and proposed model, discussed in Chapter 4, into the urban environment, and the overall results are included in the file, "Virtual Pontypridd", attached to this thesis.

Since this urban model was created, there have been numerous developments within LiDAR technology resulting in a much more accurate data collection. It is unfortunate however that due to time restrictions, the current LiDAR data will not be tested during this research. The LiDAR data used for this model was captured by InfoTerra using a laser flown from an aircraft at about 700 to 1000m. The errors in the data was around +/- 15cms in elevation, but today they can be as accurate as +/- 5cms [Leigh, 2007].

Developments in 3D CAD packages can now play a vital role in conveying understanding to a viewer such as a Client or Committee member. As technology develops the process of creating realistic 3D computer generated reproductions of real life scenery will become a much more straightforward task. The biggest problem faced by computer modellers is the complexity of the surrounding environment, and the amount of time required to produce the model, although this work may be visually pleasing, at present, the process is one that requires much time and patience. As LiDAR technology develops the number of errors will be reduced making it possible to retain the data rather than replacing it.

So far this thesis has shown that 3D technology is not being utilised within the Building Design Profession, even though trials run during this research have shown that it is attainable and feasible to do so. But is there a demand for it? Is 3D technology needed in order to enhance public participation within the planning process, in practice as well as in theory?

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CHAPTER 7: Major Survey Study

"2D plan remains legally recognized way of presentation of planning regulation. Information addressed to lay persons should be understandable for people without professional formation" [Hanzl, 2007]. However the use of 3D Computer Generated Models can "allow potential users who are unfamiliar with architectural drawing styles to better understand how a building may appear, and also allow the design team to assess their ideas from different perspectives" [Laing et al, 2002].

A vital element of the author's research is to observe how members of the general public as potential users view different presentational techniques of proposed developments.

"Within the built environment, CAD and other models have been used for a number of decades to present design ideas and solutions. Although such models have then often been used to inform consultation stages of the design process, methods already developed in other fields appear to offer much potential" [ibid].

These methods may convey more or less information than others: an architects drawing of a development focuses on the actual building and not the surrounding area; a Photomontage and Artist Impressions illustrate how the building may look in its actual environment from specific views; a Hand Made Model shows the building and maybe some of the surrounding area from any direction, while a 3D Computer Generated Animation allows the user to observe the building within its actual environment and follow a real to life route in, through, around or over it. "Many types of visualization techniques now exist, ranging from traditional 2D, artistic rendering based on interpretation of conceptual project ideas to 3D, fully detailed, animated simulation that completely illustrates all aspects of the project" [Garrick et al, 2005]. This chapter therefore, discusses an exhibition where all these techniques were put on display in order to observe which techniques were most favoured by individual members of the general public.

7.1 Public Participation and the Planning Process

"Communities and community groups across Britain are faced with ever-increasing opportunities to 'participate', yet such engagement is widely viewed as ineffective and the motives behind it viewed with suspicion" [Conelly, 2006]. "The government believes that improved access to information and wider participation of the public in decision-making processes are essential for building trust within communities, increasing public authority accountability and making better environmental policy" [Department for Environment, Food and Rural Affairs DEFRA. Cited in Higgs, 2006]. Yet the current methods of informing the public of proposed developments do not, in the authors opinion, promote or encourage a wider and more active public participation.

According to Higgs from the GIS Research Centre at the University of Glamorgan, "despite recent UK Government commitments' to encourage public participation in environmental decision making, those exercises conducted to date have been largely confined to 'traditional' modes of participation such as the dissemination of information and in encouraging feedback on proposals through, for example, questionnaires or surveys" [Higgs, 2006].

Researchers Davies, Laing and Scott from the Robert Gordon University in Aberdeen have been carrying out research into 'Choice Experiments' which has been described as a "Non-market valuation technique" [Davies et al, 2002] through the use of Computer Modelling. As part of this research respondents were presented with several design alternatives within a development and asked to "identify their preferred option" [ibid]. The research investigated how the visual impact of streetscapes could be incorporated in choice experiments through the use of Computer Generated Visualisations. Data was gathered initially through an Internet based survey, and replicated later using a high specification stand-alone machine.

Currently the methods for involving members of the general public in the planning process are limited. The use of 2D plans, sections and elevations as a form of presentation, can sometimes contain so much information that only a BDP can fully understand what information is being conveyed.

The limitations of 2D depiction are well documented:

- The image is flat, the viewpoint is unique
- The image is finite
- The image is static
- The image has a limited contrast and gamut [Durand et al' undated]

"Although it is noted that everyone should be capable of making judgments about a particular problem, it is recognised that differences in age, background, education, profession, etc, require different levels of information and interface complexity if effective interaction is to be achieved" [Kingston, 2002].

Previous chapters have looked at how members of the public are currently shown plans of developments. It is a well established consensus of opinions that those methods currently used are not suitable [Appleton et al., 2005; Bhunu et al., 2000; Bulmer, 2001; Church, 2000; and Duncan et al., 2000]. The author shares the same view. Bhunu et al [2000] stated that the current presentational techniques, i.e. Plans and Elevations are "quite difficult to understand for non-BDPs, hence the drive for 3D". Bulmer [2001] suggested that if members of the public had a greater involvement in the planning process it would promote greater understanding which may encourage more engagement with proposals in the future. According to Bulmer [2001], "Urban simulations; that is computer generated simulations of the built environment, are an effective means of improving the public's participation in the planning process"

Bulmer came to the conclusion that 3D is superior by looking at examples of where 3D has been used within the planning process i.e. Los Angeles, Edinburgh, New York, London and Bath, and interviewing 'experts, academics and creators of models'. He arrived to the conclusion that 3D was the most appropriate method of displaying designs to the public as a means to enhance participation by speaking to people who may know, and no survey was conducted to gather sufficient evidence to prove, or disprove his opinion.

Therefore, in order to investigate whether using 3D technology and VR within the Planning process will help promote understanding and increase public participation, an experiment was designed. Central to the experiment an exhibition was held, showcasing the different techniques available. This exhibition focused around a new development within the Pontypridd area, where plans for a Multi-storey car park/Office block being built adjacent to St

Catherine's Church, had been accepted. As part of the experiment, visitors to the exhibition were surveyed.

"Concurrent with the need for more effective presentation has been the rapid change of the tools used in design...however, other advances in digital technologies have also enhanced the ability of transportation professionals to use sophisticated visualization techniques" [Garrick et al, 2005]. This chapter therefore, discusses the results of a survey carried out in order to investigate the public's most favored presentational methods to be used within the planning process, and to see whether members of the public think that using this technique would encourage more people to participate within the planning process.

7.2 Pontypridd

Pontypridd is the business and administrative centre of the Taff Ely Borough, and thus has become the largest town with a population of 33,500 [ANON. 2006].

Pontypridd town centre is an example of a town in a state of decay, and as a result has suffered a significant decline in the percentage of visitors. In the 1980s, it was a thriving small town where people came from miles away along the valley road network to shop in its famous Market,

At present there is very little variation in the types of shops present in the town, with the exception of Marks and Spencers, WH Smith, Burtons and Woolworths, very few of the larger 'multiples' have remained. The citizens of Pontypridd have choice in respect of charity shops, mobile phones, food stores and Travel agents, and not much else. Over the past few years there have been a number of businesses moving away from the area such as Kwik Save and Wimpy, giving Pontypridd shoppers even less choice.

Although there appears to be a popular consensus identifying an obvious need for development within the area, all development attempts in recent times ~ such as a new Sainsbury's store, a MacDonalds, a Morrisons store on the former Brown Lennox site, plans to turn the dilapidated current precinct into a shopping Mall with Restaurants along the Taff waterfront, and plans to renovate the outdoor swimming pool area into a Plazza, ~ have all been bogged down. While these developments have not been carried out the area has become blighted, leaving it in a state of further decline.

In each of these instances, maybe a clearer view of the development, such as provided by a 3D Computer Generated Model, may have aided in the acceptance of the proposals.

However against this background of decline and a failure to develop, a proposal for a Car park development adjacent to St Catherine's church in Pontypridd called the St Catherine's Corner development has been accepted. This proposal therefore became the main subject of this research. In the previous chapter it was discussed how the CAD model for St Catherine's Corner was created and integrated into a Computer Generated Model of the Pontypridd Town. In this chapter there will be a brief discussion on the history of the development.

7.2.1 St Catherine's Corner

In July 2003 Tony Trainor, a Journalist with 'The Western Mail', a national newspaper in Wales reported that "developers have unveiled an office and car parking complex that could create 100 jobs and help revive a flagging town centre...The £7m project would be built on a site known as St Catherine's Corner, providing a 350-space public car park and 27,000sq ft of office space" [Trainor, 2003]. A model of this Car park development, has been previously discussed in Chapter 4, Section 4.2 of this thesis.

A survey carried out by the BBC in 2003 which drew a turnout of 6.4% of the overall population of Pontypridd, showed that 1081 respondents were against the car park being built, and only 302 were for the development. Regardless of the large number of those against the development, it was reported by Trainor [2003] that Jonathan Huish, a member of the Rhondda Cynon Taff cabinet for economic and community development, had said that the development was considered to be of significant importance, and that "the project is seen as an integral part of the wider regeneration of Pontypridd town centre, enabling other development projects to proceed without a loss of car parking spaces during construction" [ibid].

However due to its location, this new build, once erected would block the southern view of St Catherine's Church, and as a result has caused much controversy within the town, especially as St Catherine's Church is a "grade two star listed building, and a landmark in the town" [BBC News, 2005]. In June 2005 BBC News reported that according to the local council, the spire would still be in view, and that the development would be "a catalyst for other major projects in Pontypridd, and help traffic management". "The Labour-run authority however insists everything is in order and that the car park topped with office space is an essential catalyst for the £45m town centre regeneration scheme" [Nowaczyk, 2006]. In 2006, "Worshippers at the historic church - built in 1868 - lobbied unsuccessfully against having an eight-storey car park built on neighbouring land, arguing it will mask their clock tower" [ibid].

Wayne Nowaczyk [2006], Journalist with the South Wales Echo, a regional newspaper, reported that a council spokesman said that St Catherine's Corner will undoubtedly act as a catalyst for future regeneration in Pontypridd, becoming a landmark building and a 'gateway' to Pontypridd from the West and the Rhondda Valleys. In March 2006, the 'Observer', a local newspaper, reported of "the cutting of the first sod of the multi-million pound St Catherine's Corner development...It is the start of what we hoped to be a transformation for the town" [Observer, 2006].

The development discussed above was chosen by the author to be used within the experiment. Essentially, five techniques were used to model the proposed car park, which were then presented at an exhibition in a way that would allow for a fair response to be gathered in regards to the merit of each different technique. These different techniques are discussed in section 7.3.1 below.

7.3 Questionnaire Design and Survey

The experiment consisted of an exhibition which showcased five different presentational techniques displayed in a room at the local museum. These techniques included 2D Plans and Elevations, a Hand Made Model, Hand Drawn Images, Photomontages and a Virtual Reality/Animation, all focusing on the accepted plans for the proposed Car Park and Office block in Pontypridd.

"One of the important issues in visualization is to ensure that the visualization techniques are used in the most effective matter. Misunderstanding can result from poorly crafted presentations and visual aids. Issues such as building-in audience participation and effective use of colours and images are extremely important" [Garrick et al, 2005]

Each technique was displayed on a separate table and allowed viewers to touch, and pick up each image to analyse them more closely if required. Section 7.3.1 below discusses the different techniques displayed at the exhibition.

7.3.1 Displayed techniques

Section 1: 2D Plans and Elevations

These 2D drawings were created by the Architect to convey construction details and methods to the contractor and to satisfy planning and building regulations. They hold all the detail needed for the building to be constructed. However there is often too much detail for a lay-person to decipher and understand. During this exhibition 4 Drawings were displayed, one Site Plan and 3 Elevations.

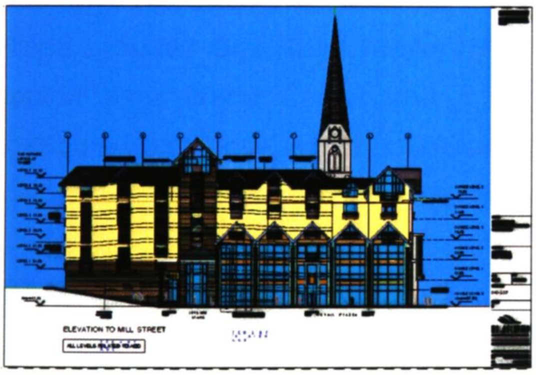


Fig 7.1: 2D Front Elevation

Fig 7.2: 2D Side Elevation

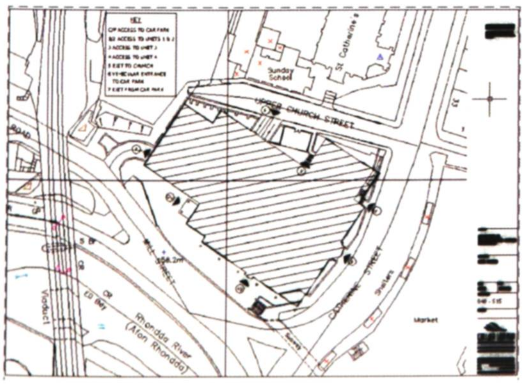


Fig 7.3: 2D Site Plan

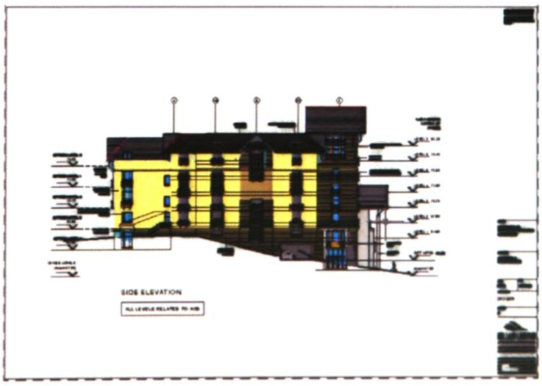


Fig 7.4: 2D Side Elevation

Section 2: Hand Made Model

3D Hand Made Model: These models are created as a means to describe how the building will look when completed. As part of this exhibition a London based Company, Richard Threadgill Associates, were commissioned to create a model so that it could be displayed, and discussed as part of this major study.

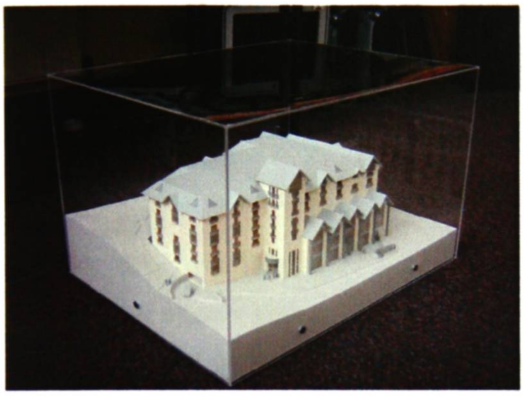


Fig 7.5: Front View of Hand Made Model

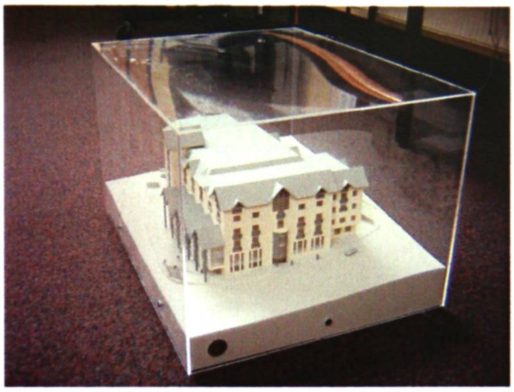


Fig 7.6: Side View of Hand Made Model

Section 3: Artists Impressions

These included One Hand Drawn image and Two Computer illustrations made to appear as a Water Colour and a Chalk drawing. Artist's impressions are "a traditional technique which is produced using pen and ink, charcoal, watercolours and sometimes oil paint to sketch, draw or paint design concepts" [ibid].

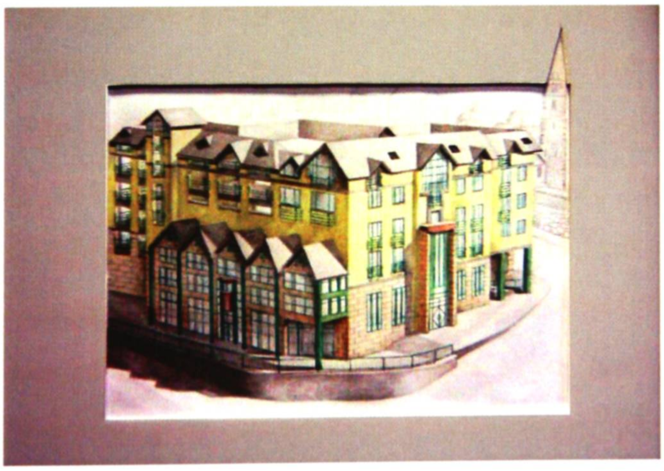


Fig 7.7: Artists Pencil Impression


Fig 7.8: Computer Generated water colour

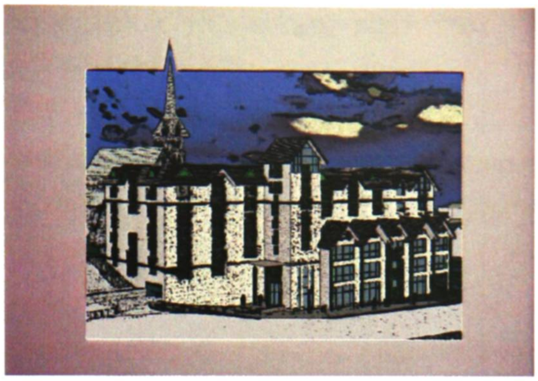


Fig 7.9: Computer Generated Chalk drawing

Section 4: VR/Animation

Fig 7.10 below shows the splash screen of one of the animations that was created for the exhibition. According to Garrick et al [2005] Animation are not yet widely used as "questions remain as to the effectiveness of animation", the results of this Survey will answer this question.

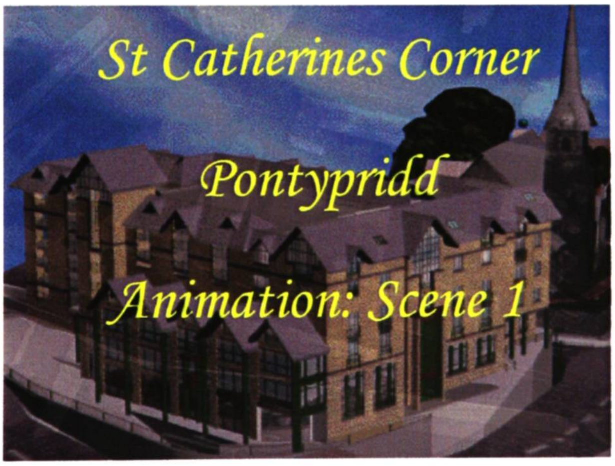


Fig 7.10: VR/Animation - Opening Scene

Section 5: Photomontages (Photorealistic Images)

According to Garrick et al [2005], Photorealistic Images are "one of the most common and powerful forms of visualization technology". The process overlays images of proposed developments onto an image of the existing environment so that the development can be viewed in its actual environment.

Although this process is a common technique, would this survey show that it is most favoured by the public who participated in this study?

Fig 7.11: Computer Generated Front View

Fig 7.12: Computer Generated Side view

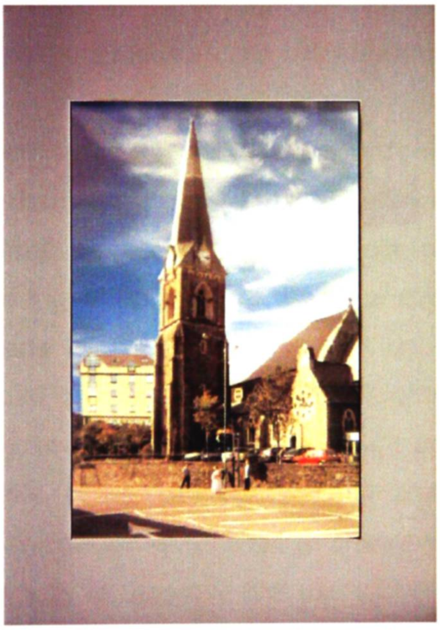


Fig 7.13: Computer generated Rear view

7.3.2 Room layout

Considerable thought had to be given to the layout of the exhibition. Initially, the primary layout of the room involved the different techniques being positioned in a linear form, thus encouraging participants to start at one end and view the separate displays in turn. The first thoughts were that the order of the techniques should depend on the amount of data shown. Therefore, the first display visited would be the 2D Plans and Elevations as this holds no 3D data, no obvious material use, and no background imagery. The second technique displayed would be Artists' Impressions, although they still do not contain any 3D data or background data they do have a much more realistic view of how the materials will appear once the building is completed. The third technique would be the Photomontages, which added background imagery into the display. This would be followed by the Hand-Made Model, which allowed the participant to view the building in 3D and to view the model from any angle. However, the Hand Made Model did not contain any background information or material detail. The final display would be the VR/Animation which contained all the 3D data of the proposed building, including the materials and background imagery.

On reflection, it was considered that the order of the displays may influence the participants choice. As more data was added, so greater understanding of the proposal would accumulate. It would be difficult for participants to be objective about which model had been most helpful and there would be a potential bias towards choosing the final techniques - the VR/Animation.

A second order was considered. This time the ordering of techniques would be changed so that rather than the techniques be positioned according to data mass, they would be positioned according to the most common to least common technique used in planning events to date. This method saw the same linear display with the 2D Plans and Elevations placed on the first table, the second technique displayed would be the 3D Hand Made Model, the third was the Artist's Impressions followed by the Photomontages. Once again the VR/Animation was positioned last, and this again caused concern that participants were being influenced towards VR/Animation even though there was no intention to lead. In fact the intention rather was to disprove the usefulness of the VR/Animation.

As a result of these concerns in regards to gathering a fair outcome, a more appropriate method needed to be designed. Eventually it was decided that to overcome this problem the models would not be arranged in a linear order, but would be positioned, around the perimeter of the room, and where the position of the entrance door would give no obvious directional influence. This would allow participants to view all models when entering the room and decide for themselves which display they would like to visit and in which order. The Hand Made Model was positioned in the centre of the room so that all sides and angles could be viewed. In order to ensure that the VR/Animation did not have an unfair advantage, it was presented on a laptop rather than a Plasma screen and placed as shown in Figure 7.14, a photograph of the exhibition room illustrating the final layout.

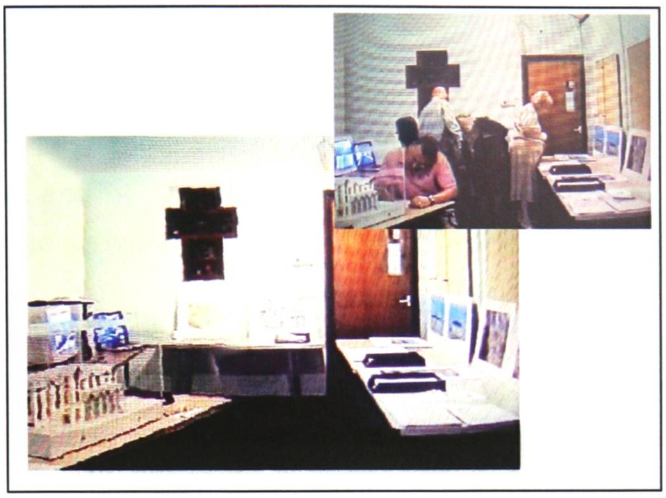


Fig 7.14: Pontypridd Exhibition room

In order to publicise the event, it was advertised in one local weekend paper. Posters were also displayed in shop windows, and fliers were handed out on the street. In order to encourage people to attend, free cans of Coke™ were given to participants.

7.4 The Exhibitions

When entering the exhibition room, the first section of a questionnaire was given out which aimed to gather general background information on the participants, such as Gender, Age and whether they lived in, or around the Pontypridd area and for how long? Once the first section was completed, participants were asked to visit different techniques on display. The second section to the questionnaire was in a form of a single sheet positioned by, and relating to each different technique, this section asked questions regarding how effective the technique is at providing information about the appearance, scale and finish of the proposed building. At the top of each sheet the participant was asked to insert their order number so that all questionnaire sheets from one participant could be identified.

To analyse which order the displays were visited, a question at the top of each sheet asked the respondent to note which table was visited first, second and third etc. It was also decided that, in order to record the behaviour of the participant towards the different techniques a video camera would be placed in the presentation room.

Other question sheets were placed with each technique and asked participants their views on the presented Images/Model/Animation in regards to;

- understanding how the proposed building will look once completed.
- understanding the scale of the building in comparison to other existing buildings, and
- understanding the finishes of the proposed building.

Responses to these questions were solicited using Likert scales with 1 standing for 'Very Easy' to understand and 5 'Difficult' to understand. The choice of 'Not Sure' was also provided for those who were not able to make preferences.

The question sheets also asked participants to note whether they believed, on a scale of 1 to 5, if the technique displayed at each table was effective or ineffective.

Once all techniques had been visited, and a questionnaire filled in, the participants were given a final sheet asking them to list the different techniques in order of preference, and whether they would be more prepared to attend local planning events if their most favoured presentational technique was used. A sample of this questionnaire and data can be found in Appendix 3.

The average length of time to fill out the whole questionnaire was 20 minutes. For those who were unable to spare this length of time, a smaller questionnaire was handed out which consisted of the first page to gather background information of each participant, and a final page which asked the participant to list techniques in order of preference. An example of this shorter form of questionnaire can be seen in Appendix 4.

The exhibition was held at 3 locations, each targeting a different section of the population. The first was held at Pontypridd Museum (Group 1) and targeted the general public, 66 responses were gathered during this exhibition. For most purposes, the non-working population cannot be assumed to accurately represent the entire (working and non-working) population. It would therefore be a mistake only to involve people in town during the day, and miss almost everyone who works except possibly for a few on a lunch break.

So the second exhibition was held at the University of Glamorgan (Group 2), in the Treforest area of Pontypridd, and targeted students, lecturers and administrators, 34 responses were gathered; the third was held during summer school (Group 3) at the same University and targeted the younger generation, 16 responses were gathered.

116 questionnaires were returned in total, 56.9% from Group 1, 29.3% from Group 2 and 13.8% from Group 3. Of the total returned, 25.9% completed the full 20 minute questionnaire which offered opportunity for a more in-depth analysis of participants' opinions towards the different techniques presented.

	Frequency	Percent	Valid Percent	Cumulative Percent
Pontypridd	66	56.9	56.9	56.9
University	34	29.3	29.3	86.2
Children	16	13.8	13.8	100
Total	116	100	100	

Table 7.1: Area of Presentation

7.5 Group 1 Analysis (Pontypridd)

The first exhibition at Pontypridd Museum achieved a response from 66 participants. The exhibition was held over 5 days, from June 13th 2006 to June 19th, and reflected the typical cross section of those who live in, and around Pontypridd on a normal week day, and were willing to participate. Of the 66 participants, 47% were Male and 53% were female.

The majority of the respondents (66.7%) were over the age of 50, however only 37.9% were retired and 15.2% were students or school children.

71.2% of respondents lived in Pontypridd, the majority of whom (53%) had lived there all of their lives.

Having seen the exhibition, the participants were asked: What is your current opinion of the St Catherine's Corner Development? 56% were in favour of the development [Strong Agreement 4.5% and Agreement 51.5%].

As previously discussed, 3 years prior to this exhibition the BBC carried out a survey to monitor the opinions of the Pontypridd public towards the new development. Their survey showed that from the 1383 of participants only 21.3% were in agreement with the development. This differs from the results shown in this exhibition.

There are several explanations' as to why these two surveys, which focused on the same development, generated such different outcomes. One possibility is that the BBC survey attracted those with strong opinions of the development where the author's survey used a random sample drawn from the general public. It is also possible that since the time of the first survey held in 2003, that the Pontypridd public had time to come to terms with the development: since 2003 numerous paper articles have been reported stating the benefits of the development. In the opinion of council leader Russell Roberts, the development will act as a "catalyst for future economic regeneration and inward investment" [Hodgson, 2006]. According to Councillor Robert Bevon, St Catherine's Corner development plays a major role in plans to place Pontypridd "back on the map, not only as a major county town but also as a major shopping destination for the South Wales valleys" [ibid]. Another possibility is that during the author's survey, the participants had an opportunity to view the development with a selection of different techniques which may have given them a clearer view of the development.

During the exhibition a Video Camera was set at the front of the exhibition room and conversations that were held between participants, or between the author and participants were videoed and analysed with the participants prior consent. Many of those who participated stated that they had expected the church to be hidden completely from view, others had never visualised the development as it would look when standing behind the church or at the side. This may have helped to eradicate fears that the new development would impact the appearance of the church and hide it fully from view. The video also showed those who had once condemned the idea of a development so close to a historical religious building, view data that offered a clearer understanding of how the development will look. Many asked questions relating to the development and were eager to know when work would commence.

When the participants were asked: What is your current opinion of the St Catherine's Corner Development? The response showed that, regardless of age, the majority of participants were in agreement with the proposal. 50% of the 10 respondents who 'Disagreed' with the development were over 70 years of age.

		What are respondents current opinions			
		Strongly agree	Agree	Disagree	Strongly Disagree
Age of Respondent	[10-19]	1	3		
	[20-29]		2	1	2
	[30-39]		4		1
	[40-49]		2	1	1
	[50-59]	1	10	2	2
	[60-69]		8	1	1
	[70+]	1	5	5	2

Table 7.2: Age of respondent and current opinion

Caroe [1995] stated that when there are new developments there could be reluctance for community members to accept a change in their home town or village. Table 7.3 below however, shows that the length of time the participant had lived in the Pontypridd area, is not a significant factor in forming an opinion on the development.

		What are respondents current opinions			
		Strongly agree	Agree	Disagree	Strongly Disagree
Respondents years living in Pontypridd	[-10]			1	
	[10-19]		5	1	
	[20-29]		3		3
	[30-39]	1	7		1
	[40-49]		1	3	1
	[50-59]		5	1	2
	[60-69]		4	1	
	[70+]	1	4	2	1

Table 7.3: Analysing years living in the Pontypridd area and current opinions

From the 66 participants 33.3% were familiar with the plan to develop, 28.8% were fairly familiar, but interestingly 37.9% did not know about the plans to develop, even though it has been an ongoing debate for several years, and has been publicised in local papers.

When asked if they currently participated in Planning events only 7.6% participated 'often' and 16.7% participated 'Sometimes'.

Table 7.4 below shows that from the 64% who never participate in local planning events, 45% were 'Not familiar' with, or had never heard of the development. It was surprising to see that , from the 5 respondents who 'Often' participated in Planning event 60% were still not familiar with the development. This illustrates one of the difficulties with participation and indicates that current advertising and participation strategies are not connecting even with those who profess interest, provided these responses are truthful.

	Respondents who participate in Local Planning events			
	Often	Sometimes	Rarely	Never
Very Familiar	2	4	3	13
Fairly Familiar	0	5	4	10
Not Familiar	3	2	1	19

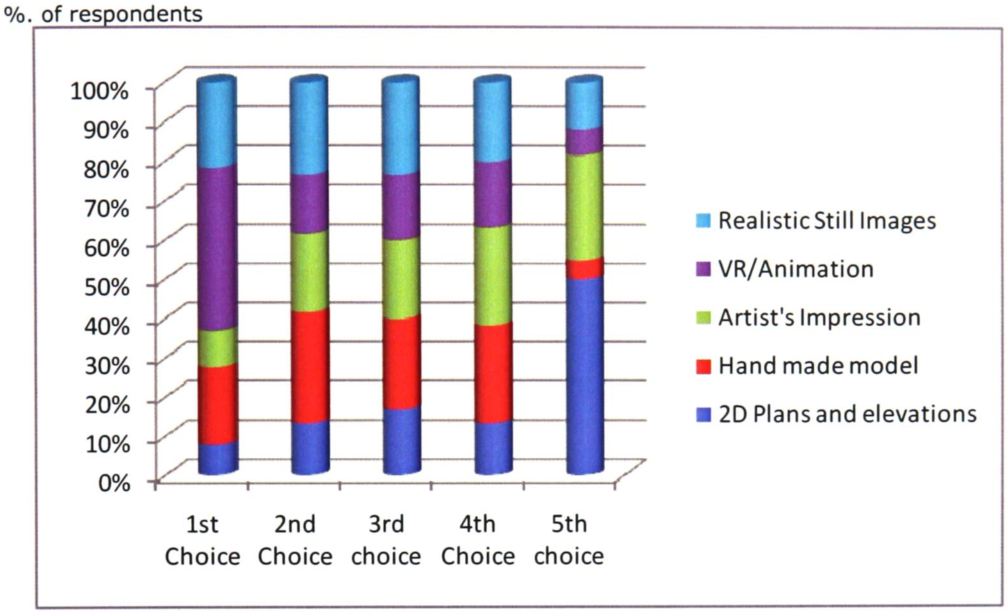
Table 7.4: Participation and familiarity with the development

The key point of this survey was to determine what technique the public prefer in regards to being shown examples of proposed developments. By asking participants to place techniques in order of preference it was possible to see which technique was chosen as their first choice, and which technique was chosen as their last choice. Table 7.5 below shows that the majority of participants in Group 1 chose VR/Animation as their first choice with 41%, the fifth choice were the 2D Plans and Elevations with 42%. This outcome was anticipated at the outset of this research, until now no proof had been provided in order to confirm this hypothesis.

	1st Choice	2nd Choice	3rd Choice	4th Choice	5th Choice
2D Plans and Elevation	5	8	10	8	30
Hand Made Model	13	17	14	15	3
Artist's Impression	6	12	12	15	16
VR/Animation	27	9	10	10	4
Photomontages	15	14	14	12	7

Table 7.5: Group 1 respondents choice of Techniques

Graph 7.6 below shows a clearer view of Table 7.5 above; the contrast between 2D Plans and Elevations on the one hand and VR/Animation on the other hand could not be more revealing.



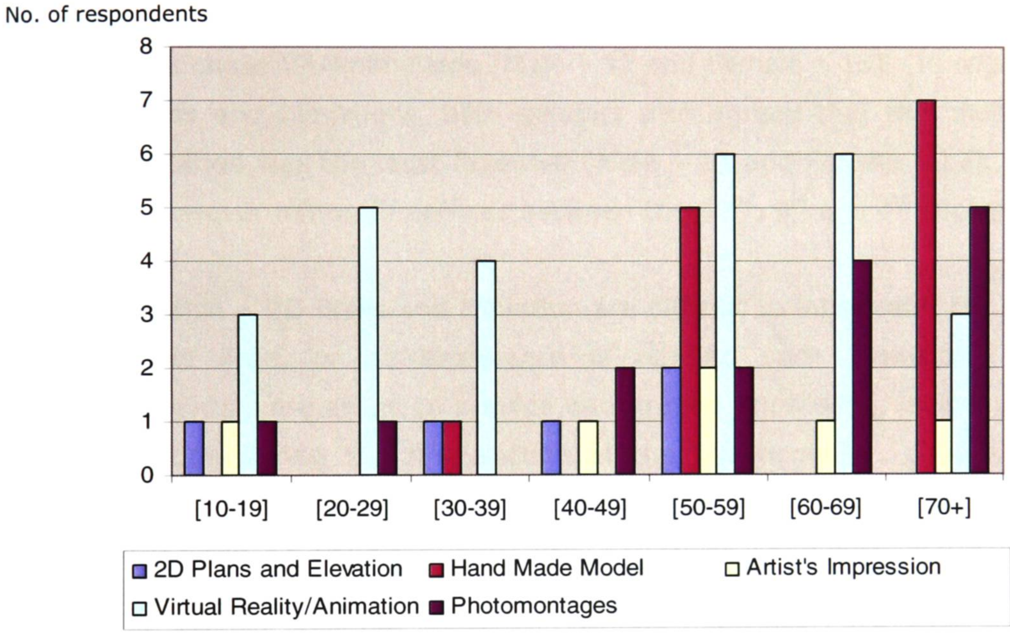
Graph 7.1: Respondents choices

There are several elements that may affect the outcome of this survey. Although it is noted that everyone should be capable of making judgments about a particular problem, it is recognised that differences in age, background, education, profession, etc, require different levels of information and interface complexity if effective interaction is to be achieved" [Kingston, 2002].

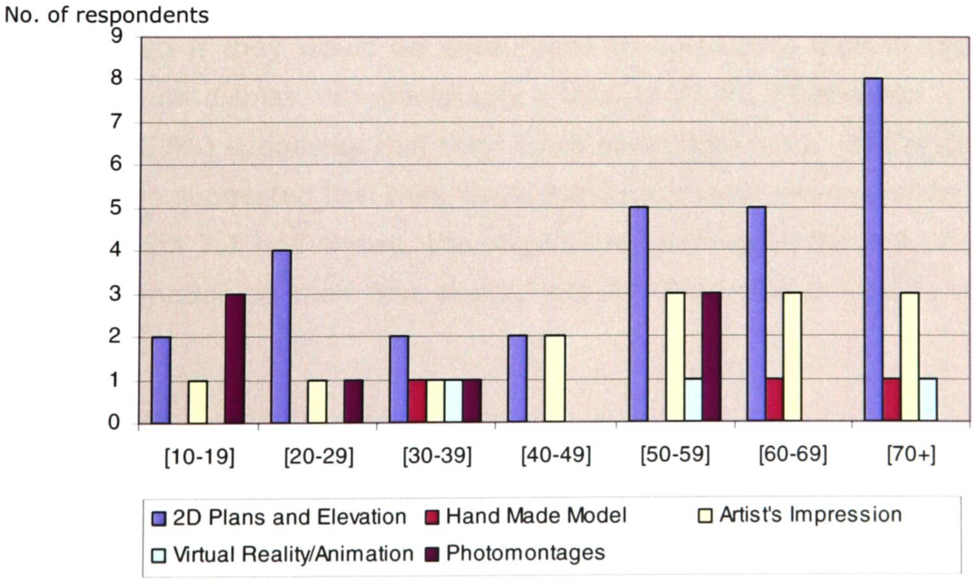
- Age – "The age of the respondent may effect the decision made during this exhibition. In regard to the Gender and the Age of the respondent 36% of female participants, and 30% of the male participants were over the age of 50.

  It could be theorised that many of those who are over the age of 50 may feel intimidated by using a Laptop and may prefer Artist Impressions, for example, as they are more commonly seen in the surrounding environment, outside of planning events. However Graph 7.2 below shows that regardless of age VR/Animation is the most dominant technique throughout all the age groups except those over the age of 70. In this latter group only 3 (12%) out of the 12 participants chose VR/Animation as their most favoured technique. Those over 70 years of age preferred the more traditional Hand Made Model and Photomontages. This would tend to confirm the theory, but the numbers are too small to generalise.

The two graphs below compare the age of the participant and their first choice of technique (Graph 7.2), and age of the participant and their fifth choice of technique (Graph 7.3).



Graph 7.2: Age of participants and their first choice of techniques



Graph 7.3: Age of participants and their fifth choice of technique

Graphs 7.2 showed that for participants under, and between the ages of 10 and 39, VR/Animation was the most popular method for illustrating proposed planning proposals, where Graph 7.3 shows that 2D Plans and Elevations were the least favoured technique throughout all the age groups.

- Gender – By Crosstabing the gender of the respondent with their favoured technique it was possible to distinguish whether there is a difference between the opinions of the two genders in regards to how planning events should present developments. In regards to their first choice both genders chose VR/Animations [Male – 12 and Female – 15]. In regards to 2D Plans and Elevations, both genders also agreed that this method of presentation was the least favoured [Male – 11 and Female - 19]. There were however minor differences between their 2nd, 3rd and 4th choices.

- Occupation – 2D Plans and Elevation are difficult to interpret if the viewer has had little, or no experience of reading such drawings. The participants were asked to provide background knowledge, including their occupation during the first section of the questionnaire. The analysis showed that the majority of participants who participated in the Group 1 survey were retired (21.6%). This will be discussed further in section 7.11.

Once the participant had chosen their most favoured presentational technique, they were asked if they would be encouraged to participate more if their first choice was put on display. Encouragingly a total of 72.7% ('Definitely' – 19.7% and 'Maybe' – 53%) suggested that they would participate more. The majority of participants who suggested that they would participate more were over the age of 50, and as Graph 7.2 had shown, the majority of those over the age of 50 had chosen VR/Animation as their first choice, and 2D Plans and Elevations as their fifth choice.

From the respondents who would 'Definitely' participate more in planning events if the technique chosen as their first choice was displayed, 29.4% chose VR/Animation to be their most favoured technique, Photomontages came second with 23%. Of course these numbers are too few to make sweeping generalisations, but it is interesting to observe that the two preferred options in this category are both susceptible to distributed and asynchronous presentation.

2D Plans and Elevations and the Hand Made Model came third in this group with 11.8% and the Artists Impressions came last with 7.7%. In regards to the participants fifth choice 46.2% chose 2D Plans and Elevations, while only 7.7% selected VR/Animation.

7.5.1 Conclusion to Group 1

Analysing the responses from Group 1 has shown that regardless of age, gender, occupation and familiarity with an area, the most preferred technique displayed proved to be VR/Animations. The least favoured technique was the 2D Plans and Elevations. There was also a suggestion that if VR/Animation was used within planning events to showcase new developments, an increase in public participation would occur.

7.6 Group 2 Analysis

The second exhibition was held at the University of Glamorgan and achieved a response from 34 participants. The exhibition was held in a large design studio at the University of Glamorgan, panels were used to reduce room size, and to create a similar atmosphere present at Pontypridd museum. During the Group 1 survey, the event was advertised in the local weekend news paper, in shop windows and on the streets with flyers. In order to advertise the Group 2 survey an invite was posted on the University web site asking for people to attend. Other participants included those who were in the vicinity at the time of the exhibition.

This exhibition was held during working hours, and therefore targeted those who are currently in full time employment or full time education at the University. Most of the participants were male (88.2%), leaving only 11.8% female. Most of the respondents were under the age of 50 (73.6%), only 32.4% of the respondents lived within Pontypridd.

Most of those who took part in this exhibition were from a professional background (61.8%), 11.8% were researchers at the University and 8.7% in each group) were Administrators, Unemployed or 'Other'. The remaining 7.6% (6) were from an IT/Technology background. It had been expected that participants with a background in IT/Technology would be biased towards the 2D Plans and Elevations due to prior experiences, however closer analysis showed that this was not the case as no participant with a background in IT/Technology, chose 2D

Plans and Elevations as their most favoured option. They did however choose VR/Animations (66.7%) and the remaining 33.3% chose the Photomontages, all three techniques were created with the use of a computer. However from the 21 (61.8%) participants with a professional background, 23.8% chose 2D Plans and Elevations as their most favoured option, this can be compared to the 38.1% who selected VR/Animations, and the 19.1% who selected the Photomontages.

Only a small number of the participants were aware of the development in Pontypridd; 73.5% were not familiar with the development and were unaware of any plans. Only once the proposal had been discussed with the participants was it possible to enquire whether or not they 'agreed' with the development. A total of 55.9% agreed with the development, 11.8% of which strongly agreed. Only 1 participant strongly disagreed with the development. This participant was male, between the age of 60-69, and had lived in the area for 10-19 years.

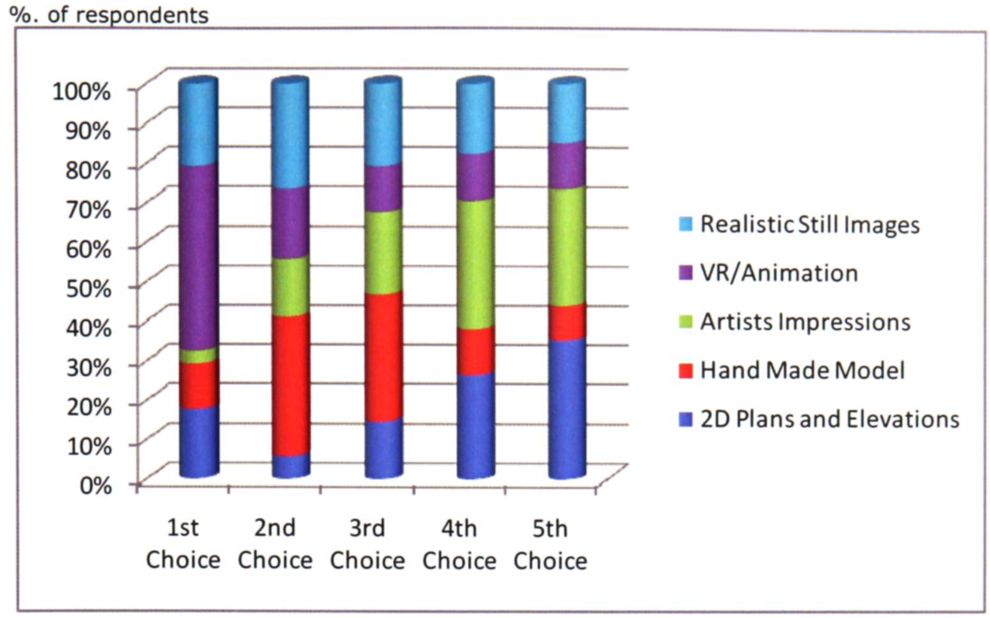
When asked if they currently participated in Planning events only 2.9% said that they participated 'often' and 8.8% participated sometimes. 58% admitted to never having participated within any planning events in their own area. (Of the 58% who never participate in local planning events, 80% were not familiar, or had never heard of the development in Pontypridd).

Participants were asked to view each display, and to list them in order of preference. Table 7.7 below shows that the majority of participants in Group 2 chose VR/Animation as their first choice with 47.1%, the fifth choice were the 2D Plans and Elevations with 29.4%.

	1st Choice	2nd Choice	3rd Choice	4th Choice	5th Choice
2D Plans and Elevations	6	2	5	9	12
Hand Made Model	4	12	11	4	3
Artists Impressions	1	5	7	11	10
VR/Animation	16	6	4	4	4
Photomontages	7	9	7	6	5

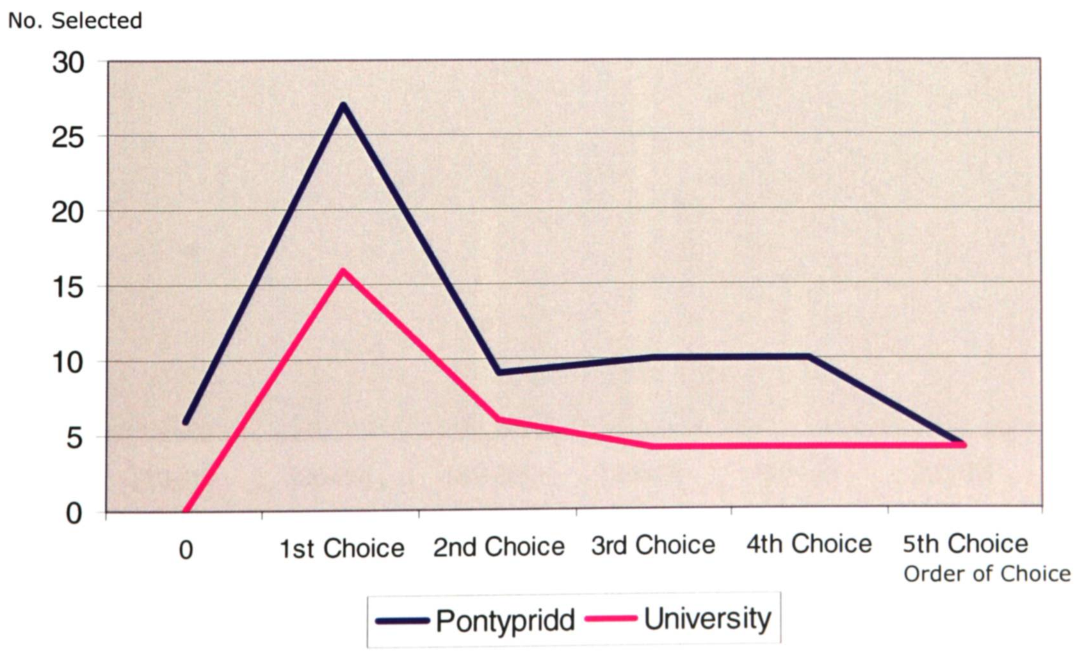
Table 7.6: Group 2 respondents choice of techniques

The graph below shows a clearer view of the data.



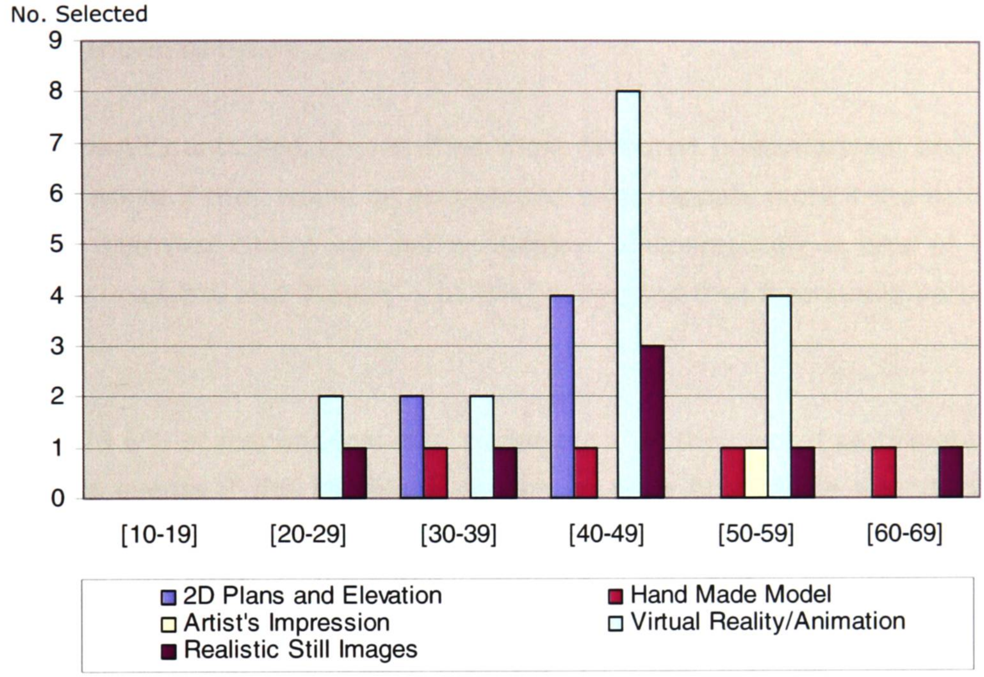
Graph 7.4: Respondents order of techniques

Those who participated in the Group 2 survey were professional members of the public, yet the outcomes remain similar to those displayed by the non-professionals who participated in Group 1. This shows therefore that, regardless of the participants educational background, VR/Animation remains the most preferred method for displaying proposed developments to the general public, and 2D Plans and Elevations remain the least favoured technique.

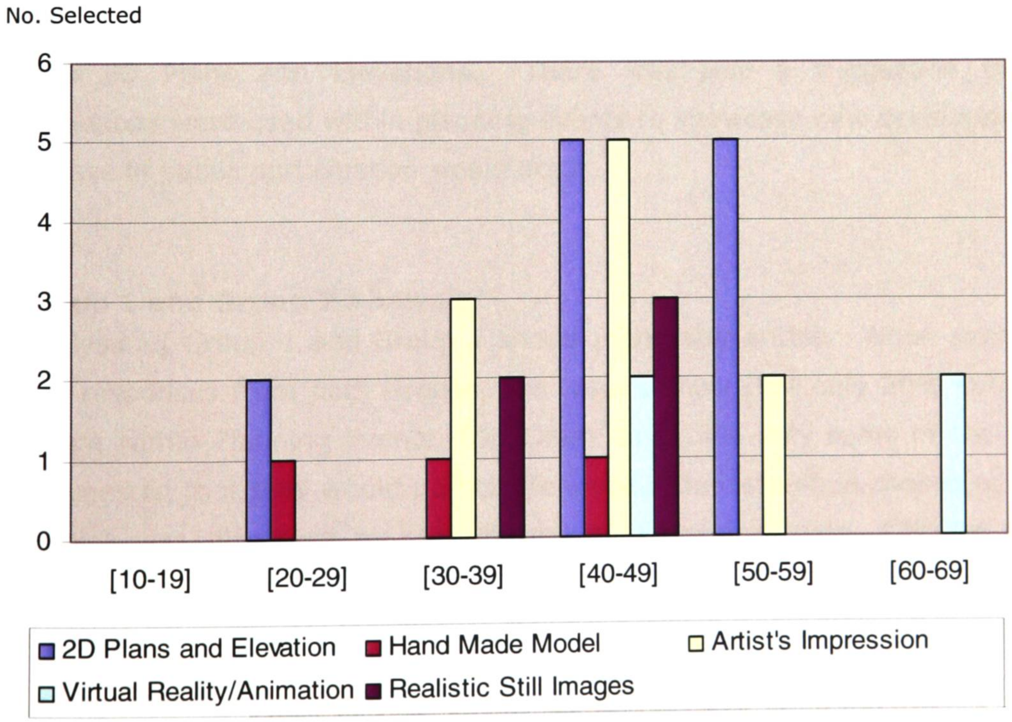


Graph 7.5: Group 1 and 2 - VR/Animation

Graphs 7.6 and 7.7 below illustrate the age of the Group 2 Participants, and their first and fifth choices.



Graph 7.6: Age of respondent and their First Choice



Graph 7.7: Age of respondent and their Fifth Choice

Graphs 7.6 and 7.7 show that participants ranging between the ages of 20 and 59 chose VR/Animation, as one of the methods chosen as their first choice for presenting plans of proposed developments. Those in the [40-49] age bracket chose 2D Plans and Elevations along with Artists Impressions as a joint last choice, as shown in Graph 7.7.

Once the participants had chosen their most favoured presentational technique, they were asked if they would be encouraged to participate more if the technique chosen as their first choice was put on display. Encouragingly, a total of 73.6% ['Definitely' – 11.8% and 'Maybe' – 61.8%] suggested that they would participate more.

From the 73.6% of respondents who suggested that they would participate more in planning events if the technique chosen as their first choice was displayed, 44% chose VR/Animation to be their most favoured technique 20% chose 2D Plans and Elevations.

7.6.1 Conclusion to Group 2

Analysing the responses from Group 2 has shown that, the most dominant technique displayed proved to be VR/Animations. The least favoured technique was the 2D Plans and Elevations. There was also a suggestion that if VR/Animations were used within planning events to showcase new developments, an increase in public participation would occur.

7.7 Group 1 and Group 2 Analysis

The analysis of Group 1 and Group 2 shows many similarities. When analysing the 100 responses from both Groups, the results show that only 20% currently participate within Planning Events, 6% 'Often' and 14% only some of the time. 73% suggested that they would participate more if the technique chosen as their first choice was displayed to present proposed developments, 17% of those would 'Definitely' attend. From the 73 participants who suggested that they would participate if the technique chosen as their first choice was displayed, 41.1% chose VR/Animation as their first option, 23.3% chose the Photomontages, 13.7% chose the Hand Made Model, 9.6% chose Artists Impressions, and only 12.3% chose the currently used 2D Plans and Elevations.

From the 73% who would participate more in the Planning process, 41% chose 2D Plans and Elevations as the last choice option, compared to 9.6% who chose the VR/Animation.

7.8 Group 3 Analysis

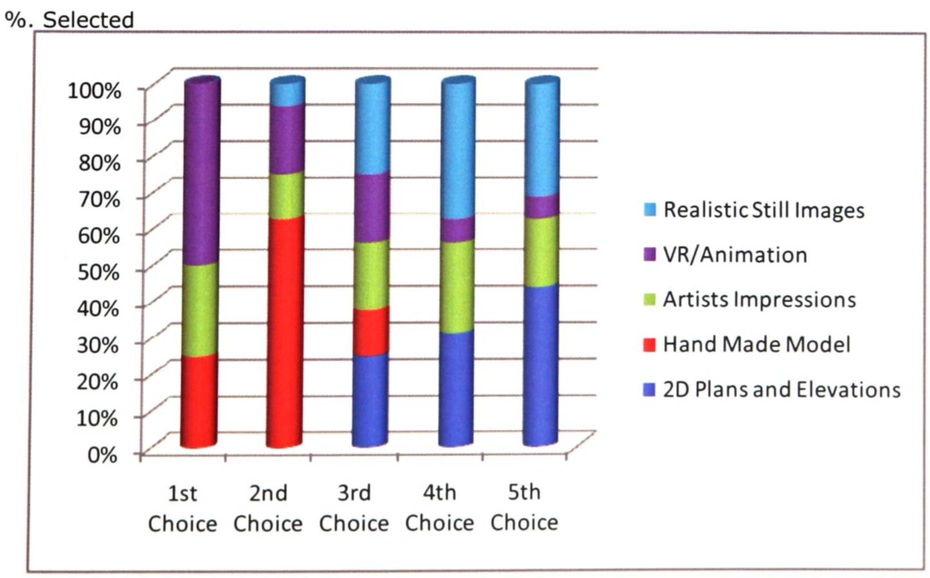
A third exhibition was held at the University of Glamorgan during 'Summer School', and focused on the opinion of those under the age of 15.

The exhibition was held in the same design studio as Group 2. Each participant was asked to view each display, in any order, and to list them in order of preference. Table 7.7 below shows that the majority of participants in Group 3 chose VR/Animation as their favoured technique with 50% of the participants selecting it as their first choice. 43.8% selected 2D Plans and Elevations as their fifth choice.

	1st Choice	2nd Choice	3rd Choice	4th Choice	5th Choice
2D Plans and Elevations	0	0	4	5	7
Hand Made Model	4	10	2	0	0
Artists Impressions	4	2	3	4	3
VR/Animation	8	3	3	1	1
Photomontages	0	1	4	6	5

Table 7.7: Group 1 and 2 Respondents choice of techniques

The graph below shows a clearer view of this Table.



Graph 7.8: Respondents first choice

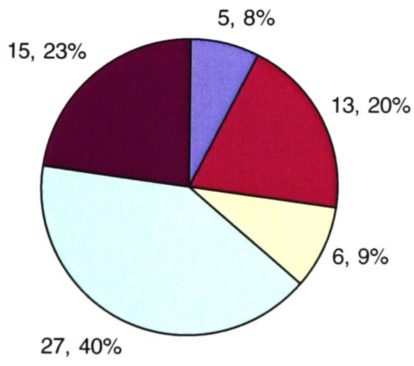
7.8.1 Conclusion to Group 3

Analysing the responses from Group 3 has shown that once again, the most dominant technique displayed proved to be VR/Animations. The fifth choice was the 2D Plans and Elevations.

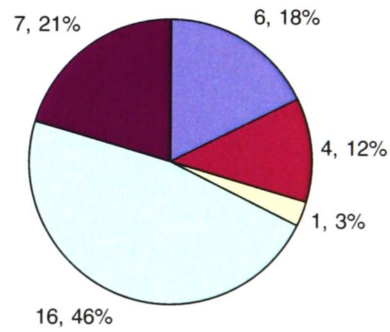
7.9 Combined Analysis

An analysis of all three groups have been very similar. When analysing the 116 responses from all three Groups the results show that 42.4% chose VR/Animation as their first option, 19% chose the Photomontages, 18% chose the Hand Made Model, 9.5% chose Artists Impressions, and only 9.5% chose the currently used 2D Plans and Elevations. This analysis has shown that there is a great need for the Planning Process to change and embrace 3D technology. Only then will the public be given a suitable opportunity to participate.

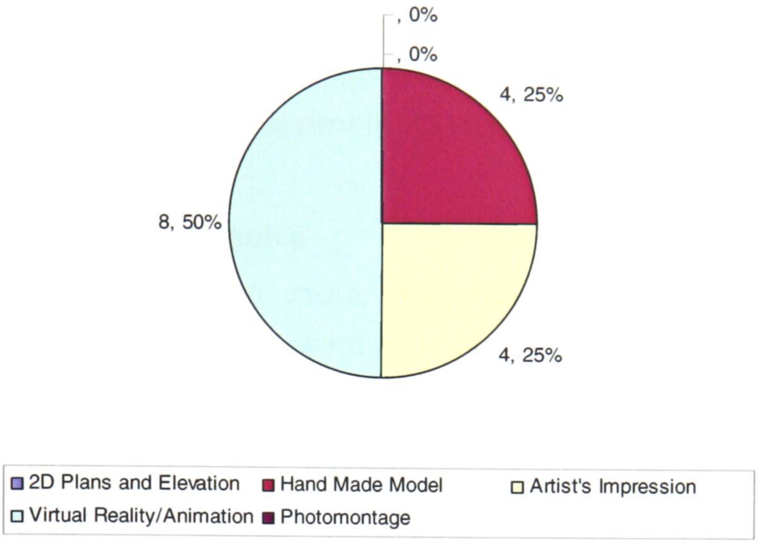
Graphs 7.9 to 7.11 below compares the first choices of all three groups, there is a similar pattern throughout in regards to VR/Animation and the Hand Made Model. The biggest difference in the pattern is that Group 3 had a higher percentage of participants selecting the Artist's impressions as their most favoured technique. This could be due to the younger generation being more used to this form of presentation due to school activities.



Graph 7.9: Group 1's First Choice

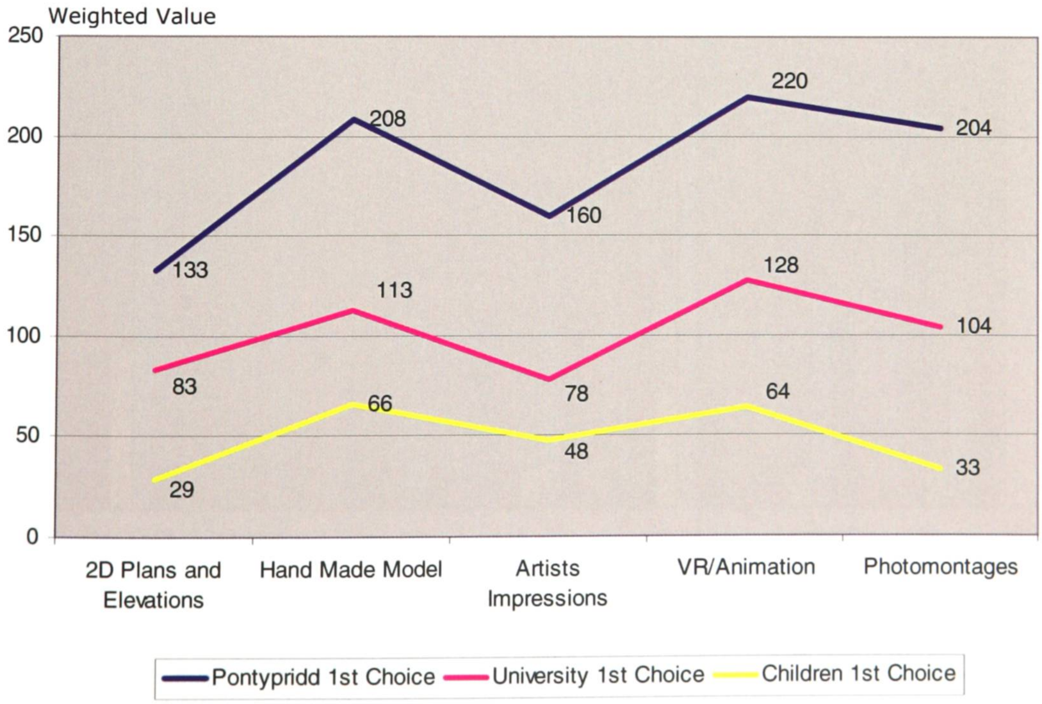


Graph 7.10: Group 2's First Choice



Graph 7.11: Group 3's First Choice

Graph 7.12 below illustrates a weighted analysis of the different presentational techniques. Each method chosen as the participants first option was given five points, second option was given four points, third was given three, fourth was given two and the fifth choice was given one point. Each point was then added and presented in the graph.



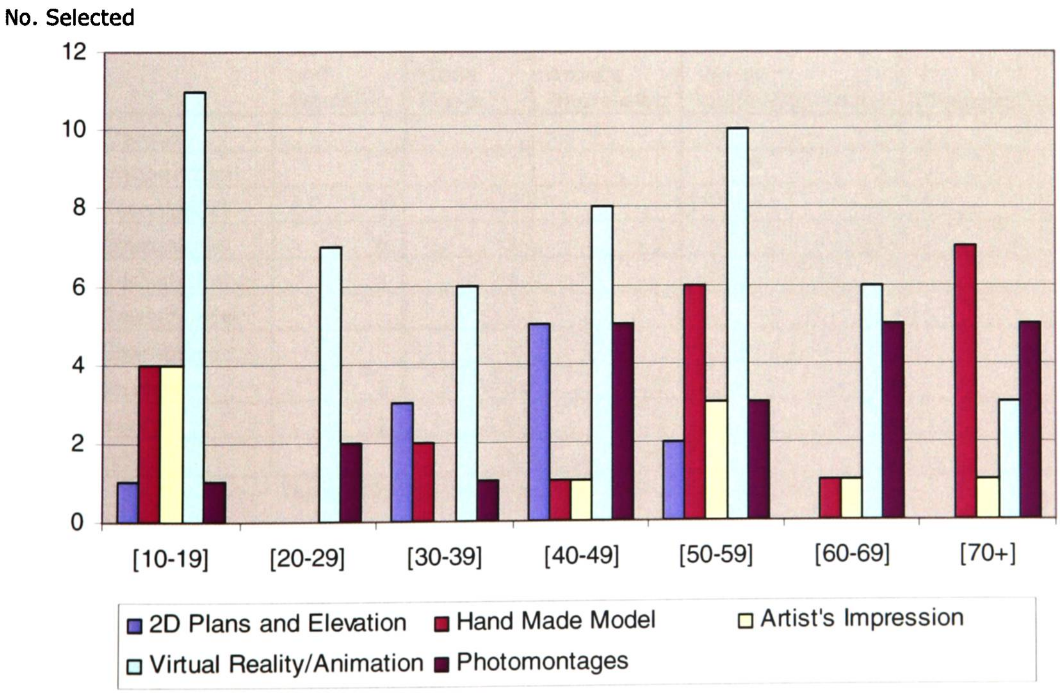
Graph 7.12: Weighted Analysis of each technique

Once again it is possible to see in the data that the similarities between the three groups showing, that overall age, profession and education has little effect on how the public react to these different presentational techniques, and that overall VR/Animation is favoured and the current 2D Plans and Elevations are not.

7.10 Virtual reality: First choice

From the 44% of those who chose VR/Animations as their most favoured technique the highest percentage were male with 60.8%, however the gender of the individual did not seem to effect the outcome, from the 68 male participants over all, 45.6% chose VR/Animations as their most favoured technique and 41.7% of the 48 female participants also chose VR/Animations as their first choice. Therefore there seems to be little difference between male and female perception of VR/Animations technique.

There also seems to be very little difference between the age of the respondent and the choice of technique, however after the age of 70 participants seemed more impressed by the Hand-Made Model and Photomontages. This has been illustrated in graph 7.13 below.



Graph 7.13: Comparing age of participants and their most favoured technique

Table 7.8 shows the reaction of different age groups towards VR/Animation. From the age of 10 to 69, this form of presentation was selected as the first choice by the majority of respondents within each age group. As shown in Graph 7.13 above, those over the age of 70 tended to choose a different technique.

	1st Choice	2nd Choice	3rd Choice	4th Choice	5th Choice
[10-19]	11	4	5	1	
[20-29]	7			2	
[30-39]	6		4	1	1
[40-49]	8	6	1	3	2
[50-59]	10	5	4	1	1
[60-69]	6	1	1	2	3
[70+]	3	2	2	5	1

Table 7.8: The comparison of Age and the choice of VR/Animation

The occupation of the individual also seemed to have had little impact on the results, as in every field other than Sales/Support and those who have retired, VR/Animation was selected as the first choice. Within the Sales/Support group the participants have chosen Photomontages as their first choice, although there is only one digit difference between the two techniques. This can be seen in Table 7.9 below.

	2D Plans and Elevation	Hand Made Model	Artist's Impression	Virtual Reality/Animation	Photomontage
Clerical				3	1
Management				2	
Technical/IT	2			7	3
Professional	6	3	2	11	5
Administrative	1	1			
Sales/Support				1	2
Unemployed		1		1	
Student	1	1	2	8	2
Retired	1	8	2	6	8
Other		3	1	4	1

Table 7.9: The comparison of first choice and occupation

For those who were more familiar with the Pontypridd area 42.6% of the 54 participants who classed themselves as being 'Very Familiar' with the area selected VR/Animations as their first choice. 44.4% of the 36 participants who classed themselves as only being 'Fairly Familiar' with the Pontypridd area also selected VR/Animation as their first choice, and 40% of the 10 respondents who were 'Not Familiar' with the area also selected VR/Animation. This demonstrates that the respondents were not influenced by their familiarity with the particular development.

During the Group 1 and Group 2 exhibitions, participants were asked if they currently participate in planning events, 38% of the 100 participants said that they 'Often' (6%), 'Sometimes' (14%) and only 'Rarely' (18%) participated. However if their first choice was selected this would rise to 73% (Definitely-17%, and Maybe-56%). From the 73% who suggested that they would participate more if their first choice was being used 41% chose VR/Animation as their first choice, where only 12% chose the more common 2D Plans and Elevations.

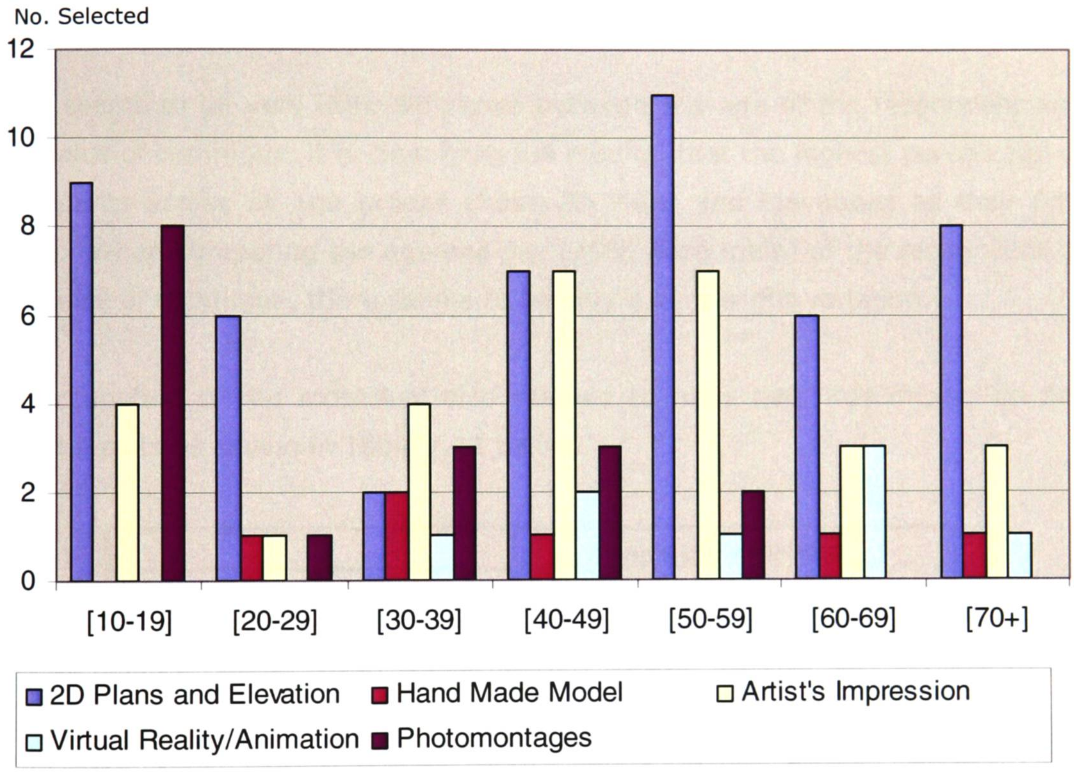
Now this minimum figure also assumes that the respondents were reflecting on what they experienced: that is, they would participate if VR/Animations were used to present proposals, and if an exhibition was made available in a public place to which they had access.

The question related to 'attendance'. But what if access to the material was distributed and asynchronous so that they were able to look at the plans at the time and place of their choosing? It seems reasonable to hypothesise that many more would participate if they had access to simulations under these circumstances and access is precisely what the internet offers. Of course access is not universal and equal, so that some groups might enjoy easier access than others. Nevertheless, on balance it is reasonable to conjecture that VR/Animations would lead to significant increases in participation in planning processes. The use of Photomontages, the technique selected as the second choice could also significantly contribute towards increasing public participation within the planning process.

These results show that there is a definite case for planners to incorporate 3D Visualization and Animation during the design process if participation is to be enhanced. Regardless of age, sex, occupation or familiarity with an area, participation will be increased with the use of this technology, and this may result in a smoother design process and a more sustainable outcome.

7.11 2D Plans and Elevations: Fifth choice

From the 42.2% of those who chose 2D Plans and Elevations as their fifth choice, 45% were male, and 54% were female, showing that there is no considerable difference between the attitudes of the male and female participants towards the 2D Plans and Elevations technique. The majority of the 49 participants who chose 2D Plans and Elevations as their fifth choice were in the age brackets [50-59] with 22.4%, Graph 7.14 below illustrates these findings.



Graph 7.14: Comparing age of participants' and their fifth choice

Table 7.10 shows the reaction of the different age groups towards 2D Plans and Elevations. From the age of 10 to 29 and 40 onwards, this form of presentation was selected as the last choice by the majority of respondents within each age group. As shown in Graph 7.14 above, those within the [40-49] age bracket preferred both 2D Plans and Elevations and Artists Impressions. However from the 11 participants who selected 2D Plans and Elevations as their first choice, 6 were professionals and 2 were from an IT/Technological background.

	1st Choice	2nd Choice	3rd Choice	4th Choice	5th Choice
[10-19]	1	2	5	4	9
[20-29]		1	1	1	6
[30-39]	3	1	4	2	2
[40-49]	5	2	2	4	7
[50-59]	2	1	3	5	11
[60-69]		2	2	3	6
[70+]		1	2	2	8

Table 7.10: The comparison of Age and the choice of 2D Plans and Elevations

There seems to be very little difference between the age of the respondent and the choice of technique, it is clear from the results, that the highest percentage of participants across all age groups chose 2D Plans and Elevations as their fifth choice. When comparing the age and sex (79% were male) of the respondent to the choice of technique, there seems to be only a very slight variation.

The occupation of the individual also seemed to have had little impact on the overall results as shown in Table 7.11 below.

		Area of Presentation		
		Pontypridd	University	Children
Occupation of Respondent	0			16
	Clerical	4		
	Management	2		
	Technical/IT	6	6	
	Professional	6	21	
	Administrative	1	1	
	Sales/Support	3		
	Unemployed	1	1	
	Student	10	4	
	Retired	25		
	Other	8	1	

Table 7.11: Occupation of Participant within each exhibition.

The analysis showed that the majority of participants in the Group 1 survey held at Pontypridd were retired (21.6%). The majority of those who participated in the Group 2 analysis, held at the University of Glamorgan, were Professional (18.1%). All 16 participants in Group 3 were school children.

These results suggest that there is a definite need for planners to change the method of displaying proposed developments to members of the general public. It is clear from these results, that regardless of sex, age, profession and familiarity with an area, 2D Plans and Elevations remain the least favourite technique throughout.

7.12 Analysis of additional data

During the exhibition 25.8% of the respondents took time to fill in the extra questionnaire (Appendix 3) that focused on the participants individual opinions about each separate technique displayed. The following analysis adds detail to the findings described so far.

The outcome of this part of the survey would tend to be biased if more professional and technical respondents participated: the expectation must be that a higher than normal degree of analytical skills could be expected. In fact, of the 30 respondents, more than half were technical, professional or managerial and additionally 1/5th were students. No clerical, administrative, sales/support or unemployed people completed this part of the questionnaire. There may be an implication here that time was not the only consideration in relation to the full questionnaire. One of the few retired member of the public who did complete the questionnaire required considerable assistance. Others simply opted not to complete it.

Also, because of the low number of participants care must be taken in generalising from these results. Apart from anything else, while this experiment concerned a real development, it was not a real consultation.

Before answering any questions related to the different techniques exhibited, the participant were asked to note which table they visited first ~ as previously stated, the exhibition room was set-up in a way that did not lead participants to any particular table. The technique closest to the entrance were the Photomontages, next to these images were the 2D Plans and Elevations, these were followed by the Artist's Impressions, followed by the VR/Animation which was displayed on a Laptop. The Hand Made Model was placed at the front centre of the room. Regardless of how the room was set, the data below, and video evidence showed that participants were drawn to the display closest to the entrance, which were the Photomontages. The biggest difference relates to the Laptop display.

	1st Table	2nd Table	3rd Table	4th Table	5th Table
2D Plans and Elevations	5	13	6	2	4
Hand Made Model	2	5	4	5	14
Artist's impressions	1	9	15	4	1
VR Animations	3	1	3	8	8
Photomontages	19	2	2	11	3

Table 7.12: Table order

As participants viewed each technique in turn, they were asked to complete a questionnaire which asked their opinion in regards to the following questions:

- How easy is it to imagine how the building will look? (Represented by A)
- How easy is it to imagine how the Size of the building will look? (Represented by B)
- How easy is it to imagine how the building finishes will look? (Represented by C)
- How effective is this form of Presentation?
- Can these drawings be improved?

2D Plans and Elevations

Table 7.13 below shows that in regards to 2D Plans and Elevations, the majority of participant found it Very Easy (36.7%) or Easy (43.3%) to imagine how the finished building will look when completed. Only 5 participants (16.7%) found them not to be very easy to interpret. Given that the difficulty in interpreting 2D Plans and Elevations is widely reported in the literature, it seems surprising that such a high proportion of participants should find it "easy or very easy" to imagine how the building will look from two dimensions. However, given that such a high proportion of respondents to the full questionnaire were drawn from professional and technical groups this is less surprising. Remarkably, even for these highly educated participants it was not so easy to imagine how the size of the building would look nor its finishes.

Another explanation might simply be that in appraising the 2D Plans and Elevations more thoroughly, especially where some of the participants had already viewed some of the alternative techniques, their answers were in some way "contaminated", distorting the final outcome.

	A	B	C
Very Easy	11	3	4
Easy	13	10	13
Not very Easy	5	11	7
Difficult	0	2	2
Not very Difficult	0	0	2
Not Sure	1	4	2

Table 7.13: Interpretation of 2D Plans and Elevations

In regards to understanding the scale of the building in respect to the surrounding area only 10% found it easy to understand and 36.7% found it less than easy, and 6.7% found it difficult.

In regards to how the finishes will look once completed the majority found it easy (43.3%). The 2D Plans and Elevations displayed at this exhibition had added colour to represent finishes, this is not often the case in planning meetings.

When asked to comment on how effective they thought this technique is at conveying understanding, 30% said that they were very effective, 46.7% thought that they were effective, 20% thought that they were not very effective and only 3.3% thought that they were very ineffective.

Hand Made Model

Table 7.14 below shows that in regards to Hand Made Models, the majority of participant found it Very Easy (60%) or Easy (36.7%) to imagine how the finished building will look when completed.

	A	B	C
Very Easy	18	5	1
Easy	11	7	8
Not very Easy	1	10	13
Difficult	0	5	6
Not very Difficult	0	1	1
Not Sure	0	2	1

Table 7.14: Interpretation of Hand Made Model

In regards to understanding the scale of the building in respect to the surrounding area only 30% found it not to be very easy, this in due to the lack of background buildings within the model due to lack of funding.

In regards to how the finishes will look once completed, the majority found it not to be very easy, once again, due to lack of funding only a basic white model could be purchased.

When asked to comment on how effective they thought this technique is at conveying understanding, 23.3% said that they were very effective, 60% thought that they were effective, 13.3% thought that they were not very effective and only 3.3% thought that they were very ineffective.

Artist's Impressions

During the exhibition 3 different types of Art methods were displayed. One Hand drawn image and Two Computer Generated images representing a water colour painting and a chalk design. The hand drawn image was most preferred from the three on display and 40% found it very easy to imagine how the building will look, and a further 46.7% found it easy.

	A			B			C		
	Image 1	Image 2	Image 3	Image 1	Image 2	Image 3	Image 1	Image 2	Image 3
Very Easy	12	10	1	5	2	4	1	1	3
Easy	14	11	5	12	6	5	10	6	12
Not very Easy	1	6	14	9	14	14	12	10	12
Difficult	0	1	8	3	7	5	3	12	1
Not very Difficult	3	2	2	1	1	2	4	1	1

Table 7.15: Interpretation of Artists Impressions

In regards to understanding the scale of the building in respect to the surrounding area only 16.7% found it to be very easy. However a further 40% found it to be easy.

In regards to how the finishes will look once completed the majority found it not to be very easy, only 3% found it very easy however a further 33.3% found it easy.

VR/Animations

Table 7.16 below shows that in regards to VR/Animations, the majority of participant found it Very Easy (70%) or Easy (26.7%) to imagine how the finished building will look when completed. Only 1 participant (3.3%) found it not to be very easy to follow and interpret.

	A	B	C
Very Easy	18	18	15
Easy	11	9	9
Not very Easy	1	3	6
Difficult	0	0	0
Not very Difficult	0	0	0
Not Sure	0	0	0

Table 7.16: Interpretation of VR/Animations

In regards to understanding the scale of the building in respect to the surrounding area 70% found it very easy to follow, and only 10% found it not to be very easy.

In regards to how the finishes will look once completed the majority found to be very easy with 50%. No one found this method to be difficult to interpret, therefore illustrating the fact that there is a growing need to incorporate VR/Animations into the planning process.

When asked to comment on how effective the thought this technique is at conveying understanding, 73.3% said that they were very effective, 23.3% thought that they were effective, and only 3.3% thought that they were not very effective.

Photomontages

Table 7.17 below shows that in regards to the Photomontages, the majority of participant found them Very Easy to understand (36.7%) or Easy (40%) to imagine how the finished building will look when completed. 2 participant (6.7%) found it not to be very easy to follow and interpret, and another 6.7% found it to be difficult.

	A	B	C
Very Easy	11	9	7
Easy	12	12	16
Not very Easy	2	6	3
Difficult	2	2	1
Not very Difficult	0	0	0
Not Sure	3	1	3

Table 7.17: Interpretation of Photomontages

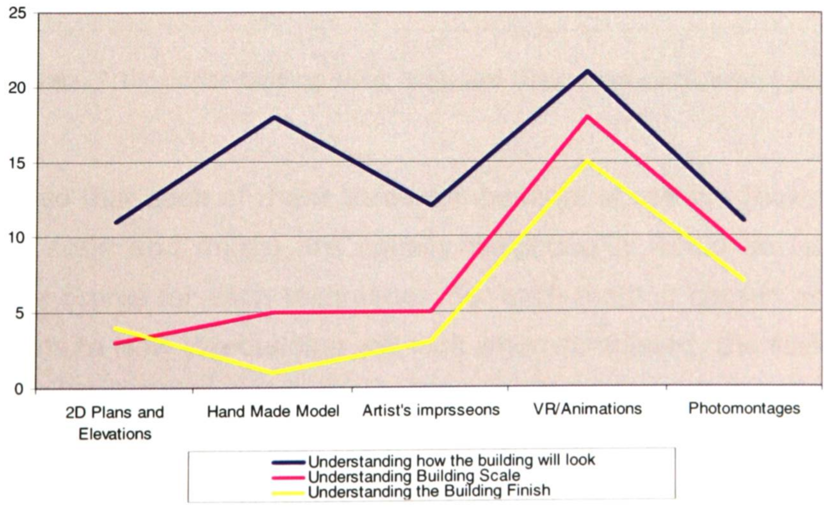
In regards to understanding the scale of the building in respect to the surrounding area 30% found it very easy to follow, 40% found it easy, and only 6.7% found it to be difficult.

In regards to how the finishes will look once completed 23.3% said that it was very easy to understand, the majority with 53.3% found it to be easy. Only 1 participant suggested that it was difficult.

When asked to comment on how effective the thought this technique is at conveying understanding, 30% said that they were very effective, 66.7% thought that they were effective, and only 3.3% thought that they were not very effective.

7.13 Comparison

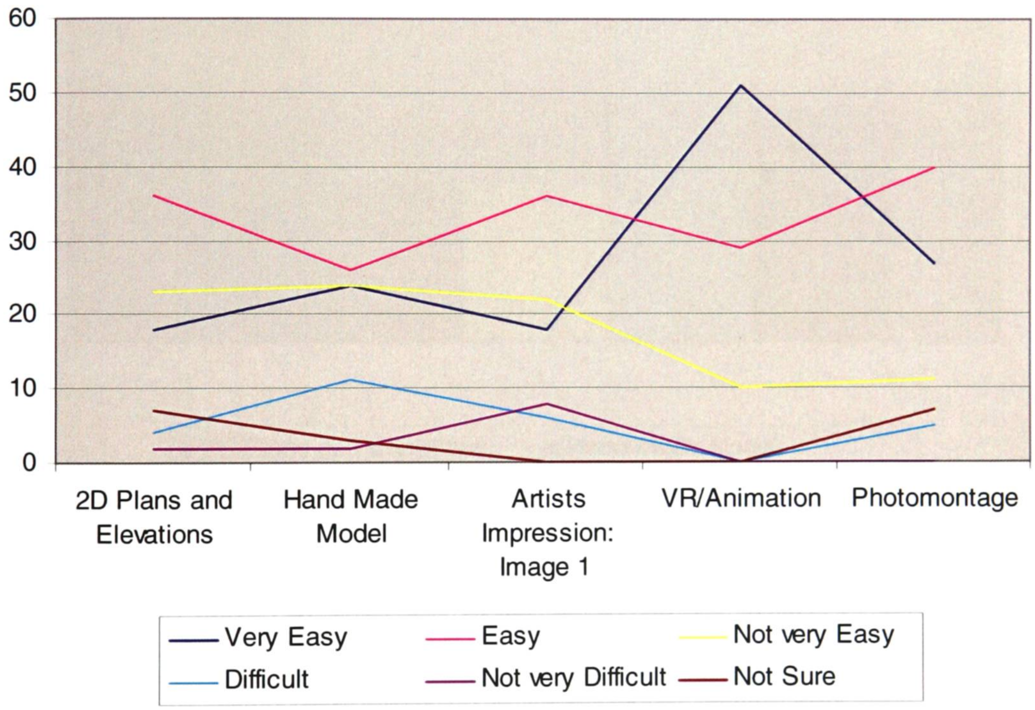
Graph 7.15 below has been created to compare techniques chosen to be 'Very Easy' to interpret.



Graph 7.15: Analysis of methods found to be 'Very Easy'

Graph 7.15 above shows that the VR/Animation display was found to be the easiest to help create understanding of a development and how it will look once completed. The Hand Made Model also had a high result when helping participants visualise how the building will look, but not how the finishes will appear, or how big/small it will appear in comparison to the surrounding buildings.

Graph 7.16 below shows that in regards to being very easy to understand VR/Animation are preferred.



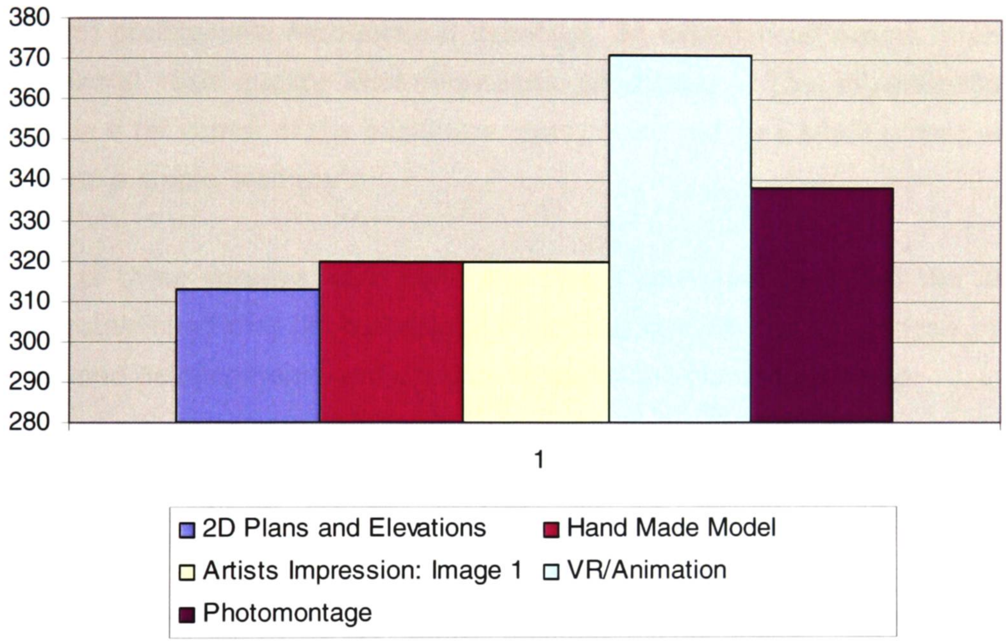
Graph 7.16: Understanding Style, Scale and Finish from each Techniques

If it is assumed that each of these three components of realism (how the building will look, its scale and finish) are equally weighted, it would be reasonable to aggregate the scores for each technique. For each method chosen as being very easy in regards to How the building will look when completed, the scale and finish of the building, five points will be given, 'Easy' will be given four points, Not very easy 3 points, Not very Difficult 2 points and Difficult 1 point. No points will be given for 'Not Sure'. Once completed, each point for each method were added.

For an easier comparison, the results showed that:

2D Plans and Elevations = 313
Hand Made Model = 320
Artists Impression = 320
VR/Animation = 371
Photomontage = 338

These results can be seen in Graph 7.17 below



Graph 7.17: Weighted analysis of each techniques.

These results suggest that in terms of the potential for understanding a proposed development, VR/Animation is more than twice as useful as its nearest rival, Photomontages. The other three techniques are clearly inferior and 2D Plans and Elevations trail again.

7.14 Conclusion

From the outset of this research the purpose has been to evaluate whether public participation will be increased if VR/Animations are provided to showcase proposed developments. In order to achieve this, an exhibition was held, the methodology and analysis of which was discussed in this chapter.

Current planning events involve 2D Plans and Elevations. However this Chapter has shown that this form of presentation was selected as the least favoured option by the participants and established that 3D and VR/Animations are required in order to develop a higher level of understanding towards a development and as a consequence to enhance public involvement.

The exhibition was setup so that members of the public could look at different presentations of a live development proposal. When entering the exhibition room the participant were confronted by a professionally crafted Hand Made Model, coloured, professional Architectural drawings, an experienced Artists Impression, and several high quality Photomontages on display. The VR/Animation was placed in a far corner of the exhibition room, displayed on a small screen and was limited to a single 'walk-by'.

A total of three surveys were held, and this chapter has discussed the findings, which established that 3D technology is needed in order for the general public to understand developments and contribute within the planning process.

The results of the survey has shown that, regardless of age and education, the VR/Animation was the first choice throughout all three exhibitions held, and 2D Plans and Elevations were chosen as the last. When asked to consider the easiest means to apprehend a proposed development, VR/Animation outperformed other techniques by a considerable margin.

When the respondents were asked if they would participate more in planning events if their most favoured techniques were used, the results showed that 56% would consider attending events, and 17% would definitely attend. Of this 73%, 41.1% expressed a first preference for VR/Animation, 30.1% expressed a preference for Photomontages. In other words, 71.1% would potentially become involved in participative processes if these techniques were widely available. Given that Photomontages can be generated from developing a 3D Computer Generated Model it would seem economic and efficient to introduce VR/Animations on a wide scale.

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Conclusion

8.1 Meeting the Research Aims

The specific aim of this thesis was set out in Chapter 1 where it was affirmed that:

"The main aim of this research is therefore to discover what type of model the public require in terms of understanding future developments, which may in turn help them engage in the planning process." (p8)

In order to achieve the aim it was quickly identified that prior questions needed to be answered. These were illustrated in Figure 1.1 of this thesis and included:

- Is 3D Technology being Utilized within the Building Design profession?
- Is 3D Technology Attainable within the Building Design profession?
- Is 3D Technology being Feasible within the Building Design profession?

In order to answer these questions, surveys and several trials were conducted. To identifying the capacity of the profession in Wales to deliver 3D models of urban environments a survey was conducted of the BDP in Wales which was designed to gauge the potential to supply visualisation services.

Chapter 4 reviewed current software products to evaluate whether 3D technology was attainable and if they were suitable for Building Information Modelling (BIM) to create a 3D model of the kind that would be appropriate for a planning consultation.

Chapter 5 reviewed data sources and data capture techniques that may help reduce the time needed for the modelling process. These techniques included GIS which resulted in a further trial being conducted in order to explore the compatibility of the GIS software with the CAD software used in the previous trial.

Having conducted these preliminary but necessary works, it was then possible to proceed to the main aim. Chapter 6 discussed how it was possible to create an urban environment using the software analysed in Chapter 4, and the data acquisition techniques from GIS data, discussed in Chapter 5, Chapter 7 then described the public's reaction to that model in the context of an exhibition that also furnished alternative, which also included the more traditional methods of presenting 2D Plans and Elevations, and a Hand-Made Model.

8.2 Findings

The starting and finishing point of the research methodology was a review of literature and current practise. The early literature search focused on identifying pioneers who may have carried out similar research: this was done, among other things, by visiting web pages, reading hundreds of articles, attending conferences, the papers of which can be found in Appendix 5, and posting a request for information on the CNBR web site.

8.2.1 3D Modelling in Practice

When the author commenced this research in 2002, despite a popular conception that these technologies held promise for urban regeneration, there had been very little research in this area: the clearest example was the Urban Simulation Team (UST) at the University of California, Los Angeles (UCLA) who were using "interactive visual simulations (VizSims) and virtual reality (VR) to accelerate the process of designing and obtaining approvals for new buildings and developments" [Delaney, 2000]. The UST established that Virtual Reality as a means to 'obtain approval for new buildings' was possible. Further literature tended to focus on the design team rather than the public.

The questionnaire survey discussed in Chapter 3 of this thesis, which aimed to gather information regarding the use of modelling software within the BDP was conducted in September 2003, . The response showed that 41% of Welsh BDPs used 2D CAD, and 28% used 3D CAD packages. The most commonly used software package, whether for 2D or 3D outputs, was AutoCAD, while Photoshop was the most popular add-on package. The use of 3D techniques was limited, and those who used 3D technology used it to communicate images to clients.

It was also established that many of the respondents could see the benefits of creating a 3D model for a proposed development, but not many had embraced the is technology. For those not using 3D technology the reasons given were related to the cost of purchasing software, training and the lengthy modelling process (see 8.2.2). Those using the software however, were more prone to talk about the lack of demand in the marketplace.

While the ability to generalise from this survey is limited because of the poor rate of response, similar surveys have been conducted by other researchers, the results of which reflect those found here. Since this survey was conducted other CAD surveys have been carried out. In 2004 Green conducted another annual survey and once again AutoCAD (57%) showed up as the most frequently used CAD package, this trend continued in his 2005 survey which showed that although AutoCAD was the most frequently used CAD package with 46%, the number had dropped quite substantially from the 57% recorded in the 2004, and the 75% recorded in 2003.

In 2006 Nigel Davies of 'Evolve-Consultancy' in Keynsham, UK conducted a similar survey to see what software UK AEC companies were using [Davies, 2006]. The results showed that AutoCAD and AutoCAD LT once again had the highest percentage of use and that The use of ArchiCAD and Revit still remained low. However, more recently, literature has suggested that market demand for 3D products is developing and the "relentless increase in demand for 3D content has inspired researchers to devise techniques which allow models to be acquired directly from the real world" [Prasad et al, 2005].

Certainly, 3D models in the Built Environment are beginning to appear, although principally in marketing where realistic environments are not required, yet there is still little evidence of this in Wales (Rao, 2007).

It is worth noting that the research reported here has most recently attracted the attention of "Pontypridd in Partnership" and the Welsh Assembly Government. Mr Mark Howland, Head of Strategic Town Centre Regeneration for RCT has requested discussions regarding the development of a "virtual Pontypridd" (June 2007).

8.2.2 Economic 3D Modelling

Chapter 3 established that BDPs in Wales seem reluctant to adopt 3D technology, chiefly due to reasons of software cost and training time. Chapter 4 demonstrated that this fear was partly misplaced as it was shown that 3D modelling can be achieved with little extra cost and less time than actually anticipated.

This was established by carrying out a trial which investigated whether current software packages are capable of producing quality 3D outcomes in a relatively short amount of time without the need of expensive training.

During this trial AutoCAD, proven to be the most adopted software package, ArchiCAD, Revit, 3D Studio Max, 3DFloorPlan and TurboCAD were all evaluated.

The trial involved each of the software packages being used to produce a model of a single detailed building, and terrain, with a minimum of background modelling sufficient to identify a location. These results can be seen in Chapter 4 of this thesis.

The results of this trial showed that as expected the lesser priced software produced poorer quality models, though the standards were generally quite high. Revit proved to be a capable software package; AutoCAD also proved to be a very strong competitor. Survey 1 discussed above, showed that 26% of respondents used AutoCAD, and as a result of this trial, it was shown that AutoCAD can be used to produce 3D models with very competitive results.

For those Building Design Professionals who use AutoCAD for 2D outcomes, a 3D model is attainable at no extra cost, with only a little training and in a relatively short length of time.

However, for those professionals willing to invest in 3D, a series of more powerful tools exist that can enhance quality and improve efficiency. During this trial several CAD software packages were discussed and analysed. ArchiCAD and Revit were products that could generate good quality 3D models in significant detail; commercial licences for these products cost £2,500 to £4,000, each plus annual subscription fees (June 2007).

Of course the absolute cost of creating a 3D model is not the key issue. Two considerations of relative cost need to be applied. The first is the cost of VR/Animations in comparison with other presentational techniques used in this milieu. For example, the costs of the models of St Catherine's Corner presented at the Exhibition described in Chapter 7 were as follows:

- the Hand Made Model cost £5,500 on the basis that there would be no time constraint on delivery and costs were quoted up to £7200;
- Hand Drawn Artist's Impressions would cost approximately £2000 for 3 images;
- 2D CAD Plans and Elevations were part of a Design & Build contract with an approximate construction value of around 8 million pounds. The fees up to planning stage would be in the region of 2.5% of the construction cost and for building regulations in the region of 1.75% of the construction cost (£340,000).
- Photomontages cost approximately £600 (If the 3D CAD model has previously been supplied : see below)
- The 3D model of St Catherine's Corner would cost approximately £5,000 and animations would be in the region of £110 per minute given the available data and current techniques but excluding the cost of software licenses.
- The cost of LiDAR data is approx £10,000 per 6km2 (http://www.bluesky-world.com/dem-lidar.html).

From this comparison the cost of VR/Animation does not look prohibitive.

The other relative measure is a comparison between the cost of developing VR/Animation and the costs/benefits of not adapting it. This is a slightly more complicated comparison. 2D CAD models have become an essential component in the development process for all developments except those at the smallest scale. However, when proposed developments impact environments that are central or popular or extensive or sensitive, public participation can be seen as a good thing, as discussed in Chapter 2. For a development such as St Catherine's Corner, there were considerable delays because of opposition, and these delays can involve significant costs for developers. In this example, it might have been useful to provide a 3D model so that objectors could have a better sense of the scale and finish of the proposal ~ this may even lead to possible changes to accommodate sensible objections. Certainly, the alarmism and hype that often surrounds developments would be opened to public scrutiny, as the facts are presented in a form that many can assimilate. It was interesting to observe that most participants in the Exhibitions described in Chapter 7 were not opposed to the development per se, whereas public opinion was portrayed as hostile.

One of the difficulties or expenses not disclosed by the Survey in Chapter 3 is the cost of terrain data. This is not surprising given that few BDPs were actually creating 3D models, and the few that were tended to rely on extruding 2D CAD drawings without much reference to actual environments.

As part of the software trial described in Chapter 4, a model was placed within its actual environment. Only a small section of the terrain and surrounding buildings were modelled, and other than the main building, no other building details, such as materials and openings were added. Nevertheless in order to place the building within this small environment a land survey needed to be conducted, and took several hours on site, and somewhat longer to process in software.

To build the style of model that would be required to demonstrate the impact of a proposed development of a large scale, a land survey would be very time consuming. As a result other methods for collecting land data were examined, with the aim of reducing the time needed to carry out a survey and therefore making the use of 3D technology more efficient.

8.2.3 Efficient 3D modelling

In Chapter 5 of this thesis, several methods for data collection were discussed, and it was established that combining data from a variety of sources could improve efficiency in creating 3D models.

This fifth Chapter therefore reports a trial conducted in order to establish interoperability between CAD and GIS data. This trial examined the file sharing capabilities between several CAD and GIS software packages as a means to disclose a procedure that could be followed in order to achieve interoperability between the two software types.

During the trial the file formats available within each software package was noted in a table, allowing for easy comparison. The results of the trial showed that it was possible to use CAD data within GIS, and GIS data within CAD, but although there are several compatible file formats only 3D Floor Plan and 3D Studio Max were able to generate a 3D model.

There was no direct method to follow in order to achieve interoperability, instead trial and error revealed a workaround that could be used to achieve the objective. Having established the possibility of opening the GIS data within 3D Studio Max it was possible to import CAD models as dwg. Or dxf. files and combine them with GIS data imported as a VRML file. This allowed for the two data types to be used in one software package where they could later be exported or rendered and animated as demonstrated during the main study. When needing to import a 3D model into GIS, this was achieved by saving the model as a 'dwg' or 'dxf' file within 3D Studio Max, or 3D FloorPlan which was also compatible, and opening them within ArcGIS. However no materials were attached to the models, and would need to be added once opened within the GIS software.

More recently as CAD and GIS each developed 3D capability, client demands for interoperability increased. The fruit of collaboration between the two principal suppliers has generated a series of new products (for example Autodesk Map 3D and ESRI ArcSDE were launched in late 2005) that came too late for the trial described in this thesis (incidentally the dwg file format is native to the new generation of products).

Chapter 5 demonstrated the possibility of combining CAD and GIS data, and demonstrated the potential to reduce the modelling process by eliminating the need to carry out a survey. Chapter 6 went on to investigate the possibility of using LiDAR Data and CAD software; 3D Studio Max and AutoCAD, to model an urban environment. For the development of the VR/Animation described in Chapter 6, this synthesis embraced digital Ordnance Survey data, LiDAR data, on-site survey data, 2D CAD files, and ground based digital photography.

In order to create the Model and Animation displayed during the exhibition discussed in Chapter 7, several steps needed to be followed:

The first step was to acquire the relevant terrain data, including building location and height data. This was achieved from LiDAR data.

The second step was to convert the LiDAR point cloud data into a 3D model, which was achieved by opening the .txt file which held the co-ordinates for each gathered point, in ArcView and triangulating the points so that a 3D surface model was produced.

The third step was to save the triangulated data as a VRML file, so that it could be imported into 3D Studio Max.

The fourth step was to open the 3D Terrain Model within 3D Studio Max using the import option from the 'File' Menu. Once within 3D Studio Max the terrain data was modified using the 'Edit Mesh' tool until realism was achieved. The Lidar data used during the course of this research proved to be helpful, but of poor quality: from a distance only small defects within the data could be seen, however on closer analysis such as from a pedestrian view, the data contained a large amount of noise, and as a result needed to be replaced. This resulted in the original data being removed and replaced with smoother geometrical shapes to represent pavements, roads, buildings and other objects found within the urban scene.

Once the model was completed an animation could be produced, achieved by placing a virtual camera within the model at the desired height, and creating a path using the 'line' tool to mimic a pedestrian walk-by and an aerial path for a fly-over. Once the Animations were created they could be exported as an .avi file to be viewed on a PC.

These trials suggest that it is possible for Building Design Professionals to create models that will "walk" their audience through a development before it has been built. But is it what people want?

8.2.4 VR/Animations and Public Participation in Planning

Early literature did not disclose a suggestion that any research was being carried out in regards to the impact of 3D Modelling on public participation in the planning process.

Similar to the research carried out by Appleton discussed in Chapter 2, Section ? of this thesis, this research has also indicates that members of the public have trouble understanding 2D Plans and Elevations, however this difficulty does not extend to all members of the public, at least not in relation to all aspects of perception. There is a suggestion in the data that managerial, professional and technical participants had less difficulty interpreting 2D Plans and Elevations, 80% of a small sample found it easy (43.3%) or very easy (36.7%) in regard to how the finished building will look when completed.

Nevertheless, current, research establishes that people struggle to understand 2D Plans and Elevations, theoretically and now empirically.

What distinguishes this research from Appleton's is the experience it provided for members of the public to comment on alternative techniques of presenting a proposed development. The exhibition provided data of the publics perception of existing techniques and also of potential new techniques. Whereas Appleton concludes that people "struggle to turn 2D maps and plans into 3D mental images" and this research concludes that people have a preference for 3D visualisations over 2D. Moreover, for the first time, it is possible to put a number to people's preferences.

The data consistently demonstrates that more than 40% of participants chose VR/Animation as their first choice and that more than 60% would choose either VR/Animation or Photomontages to convey this type of information. Interestingly, this result is not overwhelmingly in favour of VR/Animation.

Of course it is possible that some folk are just unsure about VR. As Appleton's research makes clear, for most people, these technologies are outside their experience, and it will take time to adapt. At this point too, it is worth remembering that the VR/Animation displayed during the exhibition held as part of the major study was presented on a laptop in a dark corner of a room! When it had been presented on a large flat panel screen in the Boardroom of 'Pontypridd in Partnership', albeit to a managerial/professional audience, the impact was quite different, generating unanimous enthusiasm.

The results of this survey data also revealed that 56% of participants would more likely participatory in the planning process if the techniques that help them were available. Given that the two most preferred media could be made available online, this points the way to a potential step change in participation in urban planning processes.

What flows from these observations is that the changes needed to be made within the planning processes in order to public participation, may not need to be systemic but rather technical. It is possible for technical change to sometimes trigger cultural changes, especially when the technical changes have the potential to increase understanding and strengthen democratic processes. Perhaps the real challenge is to those that hold power in the existing planning system. The real cultural challenge may be a release of existing techniques by those empowered by them.

8.3 Contribution to Knowledge and Understanding

This work began with the author's personal quest for knowledge and the purpose of this research has been to examine the importance of 3D Visualization within the Planning Process, and address the issue of improving public participation within urban regeneration. The starting point was that the inclusion of public opinion should be normative in regards to planning and urban regeneration.
In addition to any general contribution to knowledge, the conduct of this research has identified that:

- The various processes that are in development for representing 3D models of real world objects are complex and overlapping. The literature review was important in identifying these various processes and techniques from a variety of perspectives that offered different classifications. The literature review in a sense offers its own classification of these techniques and has been helpful.
- Evaluating the possibilities inherent in the collection of techniques that are labelled "software" required the development of criteria capable of evaluation. While ultimately these criteria could not drive out subjectivity entirely, formulating them was a useful exercise and gives confidence.
- The development of workarounds in establishing a process capable of generating 3D models has not outlasted this thesis! However the methodological approach is more permanent: examine software, examine transferability of file formats and interoperability, identify potential intermediary software products, and produce method statements. This is lasting.

At the outset it was recognised that there are a variety of problems associated with the issue of truly representing public opinion: for example defining 'public' or resolving disputes and ambiguities. This research was not concerned with these aspects of public policy but was more specifically interested in technical barriers.

This work proceeded on the basis that using an appropriate 3D Virtual Model, with its potentialities in Visualisation, can provide urban designers with a powerful tool to enhance the design process and public participation within it, allowing communities to have a greater say in what a development should bring to an area. Logically, such a process would improve the sustainability of development.

Other researchers have also identified a link between 3D modelling techniques and public participation, however, this research demonstrated the validity of these expectations, and gave percentages to key questions such as: how many people would choose VR/Animation over more familiar techniques, and how many people would engage in planning processes were those techniques available?

The exhibition enabled members of the public to gain experience of the different presentational techniques available to display proposed developments, and an entirely novel approach. During the exhibition the VR/Animation was placed in a far corner of the room, displayed on a small screen and limited to several set paths that did not allow interaction, it was not used in anyway to draw participants to the VR/Animation but, instead was setup more as a means to disprove the thoughts from which this research originated. This gives greater confidence that the investment of developing 3D models, will be worthwhile and that VR/Animation should be normative in the planning processes.

There were a number of questions that needed to be tackled during the course of this research. These questions related to the use of 3D technology within the BDP, whether the technology could be harnessed to produce the required outputs; whether it was technically feasible, and efficient and whether it would be wanted by the general public.

Through the conduct of this research the following points have been sufficiently established in answer to the questions:

- 3D Technology is not being utilized for planning processes ~ definitely not in Wales and probably more generally.

- 3D technology is quite capable of producing models that are effective in communicating development plans efficiently.
- More than 50% of respondents to a survey chose VR/Animation as their first or second choice as a means of engaging with planning proposals suggesting sufficient latent potential demand to warrant further consideration.

The main study involved the organisation of three separate exhibitions were held which targeted those from different backgrounds and age groups. An overall total of 116 people participated in the exhibitions. The results has shown that, regardless of gender, age and education, VR/Animation was the preferred choice in regards to understanding a planning proposal, and the 2D Plans and Elevations were placed as the last choice. When the respondents were asked if they would participate more in planning events if their most favoured technique was used, the results showed that 56% would consider attending events, and 17% would definitely attend. With the adoption of 3D technology there may be a 56% rise in public participation. Even if the more modest 17%, who state that they would definitely attend actually became involved, a massive transformation of the participation process would occur.

Although it has been shown that 3D and VR/Animations would enhance public involvement, this research has shown that presently, the design profession has not yet fully adopted this method of presentation, and as a result it is rarely used within the planning process. This clearly frustrates effective public participation. At present there is low awareness within BDPs and planning bureaucracies of the importance of using 3D CAD software packages, caused due to lack of awareness as prior to this research being conducted the public have not been asked. There is still a need for 2D Plans and Elevations to be produced but as a means to illustrate information to the construction team, not the general public.

8.4 Further research

- The final form of the 3D model in this research ~ VR/Animation delivered by computer ~ was driven by questions of software and data availability and by considerations of professional efficiency and economy. These issues were mediated through the subjective views and decisions of the author. For example, a decision was made to reduce the complexity to members of the public by creating an Animation over which there was no end user control. A view was taken in which the least immersive form of VR was adopted. In these ways the public were excluded from the development of the model on which they were asked to comment.

An alternative possibility exists, in which the modelling process starts with members of the public and key decisions that have been assumed by the author are opened up for public discussion, thus democratising this part of the process. This kind of approach might be organised through focus groups. A variation on this, especially in relation to technical aspects of the process where the public might not have much to say, would be a Delphi group, where the opinions of experts might be elicited in order to develop a consensus.

- Data acquisition techniques are developing rapidly. Since the trial it has been possible to use new scanning tools that will further improve efficiency and accuracy. Recently, the University of Glamorgan has acquired pseudo CAVE technology at considerable expense and two 3D Scanners further work will now be conducted using this medium.

- Since this urban model was created, there have been numerous developments within Lidar technology resulting in a much more accurate data collection. The errors in the data were around +/- 15cms in elevation, but today they can be as accurate as +/- 5cms [Leigh, 2007]. The development in Lidar data may result in a quicker modelling process and should be examined further.

- New software products have been designed to integrate data from CAD and GIS sources, providing new 3D capabilities (the most recent was launched as this thesis was being prepared for press). In their first incarnations these products amounted, arguably, to no more than a formalisation of the workaround developed here (as Fig 8.1 hints). The trials conducted in Chapter 4 and 5 of this research could be extended to include these newly developed software packages.

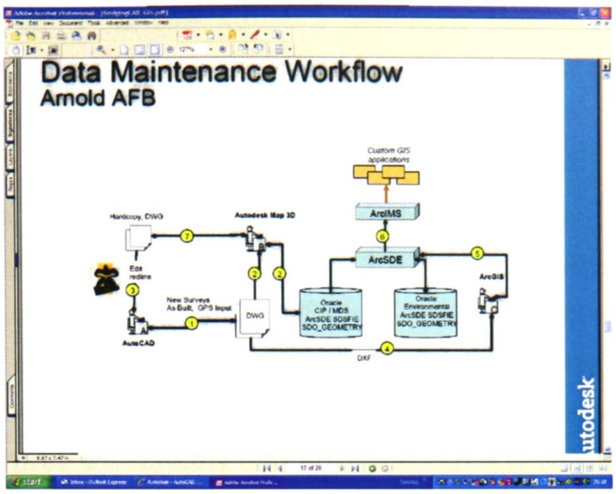

Fig 8.1 A description of workflow in Autodesk Map 3D
Source: Bridging the Gap, 2005

- The consultative process described in this thesis touched on real opinions about a real development. Ultimately, however, the consultation was artificial. The next logical step is a real consultation about a real development.

- Considerations of economy also excluded some avenues of research. The recent acquisition of a more appropriate platform by the University of Glamorgan and the possibility of collaborating with other Welsh Higher Education Institutions through a network being established by the WAG provides opportunities for further research in more immersive media.

- At the close of this research, new questions come to the fore. Will the techniques advocated and demonstrated here gain a foothold in real practice? Some technologies seem to be adopted, sometimes very quickly. Other equally promising technologies seem to hit against hidden and unforeseen barriers. Will the techniques reviewed here be implemented? Will there be opposition and if so, where does it lie and how will it be expressed? The author intends to stay in touch with these issues.

- Finally, what about doing it all again! What about starting from the very beginning on the basis that technological development has proceeded apace and that a nearly-new formulation of the problem may be possible.

Recently it came to the author's attention that a PhD has just been registered at Glamorgan that seeks to examine the question of whether GIS might assist public participation!

But no, this road has already been travelled enough. Five new pieces of software learned (Revit, ArchiCAD, 3DFloorPlan, TurboCAD, and SPSS), two trials conducted, one to examine the different CAD packages, and another to explore the possibilities of interoperability between CAD and GIS, two surveys conducted, one of the BDP in Wales and one members of the public, three exhibitions and many versions of models to display there, two conference papers produced and countless publications read.[26] What was once an intellectual challenge has been answered sufficiently now to have become a commercial challenge!

8.5 Final Words

This work has proven to be unique, no other research has been found like it in this subject area. The work carried out has been creative in the way that it approached public participation, and developed data for public input in order to depict what is needed within the planning process.

From the methodology used, an accurate account of what is needed within the planning process seems to have been realized. The methodology used, and the process followed have been critical to this study, and possibilities and limitations have been noted and will assist future research.

Recommendations from this line of reasoning are that:

- Planner/Developers should think more seriously about making 3D models available, the cost is relatively small and may be self funding. It is recommended that honest, non-deceptive, 3D imagery and VR/Animations be adopted to aid the consideration of a development by gaining the trust, and perhaps the backing of the public. The results of this research has shown that this method of presentation helps aid understanding by the

[26] I am indebted to others in this process. The 2D Plans and Elevations were supplied by 'WilldigLammie', an Architectural company in Wales. The Hand-Made Model was produced by 'Richard Threadgill Associates', London, and the Artists impression was supplied by Mr Nathan Jones of Pontypridd. The three Photomontage images, two computer generated artistic impressions and VR/Animation were all produced by the author.

public, and may therefore be the key to the acceptance of future developments not only within Pontypridd, a deprived and decaying area, but other towns and villages.

- the BDP should consider those occasions when they would recommend to their clients the use of 3D models for consultation. It is recommended that the adoption of 3D technology is a must for future designs to increase the possibility of acceptance and to reduce the need for costly resubmissions of applications.

- For Government members the recommendation is to meet its declared aim of enhancing participation by facilitating and patronising the development of 3D modelling, at the same time, those committed to public participation in the planning process might consider grant aiding the development of 3D models to assist the objective. Initially, a series of pilot projects might be recommended that further examines the findings reported in Chapter 7.

  The impact of failure to develop is a consideration. Town managers might also have cause to prime this pump in view of the blight caused by development inertia (as has been witnessed in Pontypridd).

- The final recommendation is to members of the public, to those who do not participate, those who walk past developments once completed wishing that they had stood up and made their voices heard, to these people the recommendation is simple, take notice, take part and make a difference.

Since the experiments reported in Chapters 5 and 6, a number of developments give confidence that even more efficient 3D modelling could soon underpin public participation.

It is believed that this research has provided new and strong evidence that is valid as work at a doctoral level. The major study required great attention to detail, although simple in its prosecution, its results have proven to be useful for planning departments and all involved with development, and particularly those affected by development.

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Developing the Opportunities Together. 20 March 2007. Waterton Centre, Bridgend.

APPENDIX 1

"A table was devised within an Excel document where all information regarding books, Journals and websites are listed. The number of references from each piece of Literature is noted, and a hyperlink added to a word document where reference details and quotes are stored".

Architectural Vizualisation Literature Review

JOURNALS

Title of Article	Name of Journal	Written by	Date	Volume	Page	Quotes	Accessed/Read	About	Find
Digital Imaging in Architectural Design E-ducation	Journal Vine	J Verbeke, S Brussels,M Stellingwerff	2002	vol 32 Issue 128	22-30	3	May-03		Folder 1
Modelling Cities one segment at a time	IEEE Computer Graphics and Applications	G Singh	Nov/Dec 2003	vol 23	4 to 5	3	Jan-04		Folder 1
An effective Environment for Real Time Community Visualisation	?	William Jepson and Scott Triedman	?	?	?	3	Dec-03		
V Village R - Futuristic housing in a socially mixed neighbourhood in Helsinki	Paper presented at 'The 6th Sharjaha Urban...	Pennanen et all	2003	?		1	Jan-04		Folder 1
The 3D City Model - A New Space	Modelling and City Planning	Steen et al	2001	?	430 - 435	5		Internet Thought	Folder 1
Real-Time Visualisation of big city models	International Archive of the Photogrammetry	Michael Beck	2003	Vol.XXXIV-5/W10	p1-p6	2	Jan-04		Folder 1
New methods of Digital Modelling of Historical Sites	IEEE Computer Graphics and Applications	Peter Allen et, al.	Nov/Dec 2003	vol 23	32 - 41	3	Jan-04	Quote: 3D Scanner	Folder 1
For New Buildings, Digital models offer an advance walk-through	New York Times	Marriott, Michel	04-Mar-04			1			
Architectural Practices And Their Use Of It In The Western Cape Province, South Africa.	Itcon	Arif, Azza and Karam, Aly.	01-Sep-01	Vol 6	pp 17 - 33	1	Sep-04		ARCH VIZ
Industrial Applications Of Virtual Reality In Architecture And Construction.	The Journal of ITcon	Whyte, J	May-03	Vol 8	pp 43 - 50	1	Sep-04		
Realistic real-time rendering of landscapes using billboard clouds	Journal of Eurographics	Behrendt, S. Colditz, C. Franzke, O. Kopf, J. Deussen, O.	2005	Vol 24 No. 3		1	Sep-05		
Peering through the smoke? Tensions in landscape visualisation.	The journal of Computers, environment and Urban S	Matthew.	2005	Vol 29, Issue 3 ,	May 2005, Pages 341-359	1	Oct-05		
The role of spatial metrics in the analysis and modeling of urban land use change.	The journal of Computers, environment and Urban S	Herold, Martin. Couclelis, Helen. Clarke Keith.	2005	Vol 29, Issue 4 ,	July 2005, Pages 369-399	1	Oct-05		
Approaches to simulating the "March of Bricks and Mortar"	The journal of Computers, environment and Urban S	Goldstein, Noah. Candau, J. Clarke, C.	2004	Vol. 28, No. 1.	125	1	Oct-05		
3D-GIS in networking environments.	The journal of Computers, environment and Urban S	Coors, Volker.	2003	Vol 27, Issue 4	July 2003, Pages 345-357	1	Oct-05		
3D spatial relationships model: a useful concept for 3D cadastre?	The journal of Computers, environment and Urban S	Billen, Roland. Zlatanova, Siyka.	2003	Vol 27, Issue 4	July 2003, Pages 411-425	1	Oct-05		
Innovation & Technology North Wales, DEIN: Visualisation in Wales - Developing theOpportunities Together	Welsh Assembly Government Summary Report to:	Jeniffer Rao. Waterton Centre, Bridgend.	20 March 2007.						

BOOKS

Title of Book	Printers and Place	Written by	Date	Chapter	Page	Quotes	Accessed/Read	About	Find
Computing in Architectural Practice	E + FN Spon / London	Christopher Woodward + Jaki Howes	1997	3	89 -112	8	May-03	Use in Arch Visualization	Folder 1
Computing in Architectural Practice	E + FN Spon / London	Christopher Woodward + Jaki Howes	1997	5	129-135	2	May-03	Use in Arch Visualization	Folder 1
Selling Architectural Ideas	E + FN Spon / London	Tom Prter	2002			1	May-03	Use in Arch Visualization	Folder 1
Visualization in Landscape and Environmental Planning: Future use for Augmented Reality for environmental and Landscape Planners.	Taylor and Francis. London.	Piekarski, Wayne. Thomas, Bruce. 2	2005	10	234-240		Sep-05		
Visualization in Landscape and Environmental Planning: Combining visualization with choice experimentation in the Built Environment.	Taylor and Francis. London	Laing, Richard. Davies, Anne-Marie, Scott, Stephen.	2005	9	212-220		Sep-05		
Visualization in Landscape and Environmental Planning: Helping Rural Communities envision their future.	Taylor and Francis. London	Stock, Christian. Bishop, Ian.	2005	7	145 - 151		Sep-05		

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The small Practice Architects Tale	www.cadserve.co.uk/common/viewer/archive/2002/Nov/11/feature	?	1	May-03	Allpaln 3D Visualization	Folder 1
Building a Virtual World Offsore	www.cadserve.co.uk/common/viewer/archive/2002/March/22/feature 15.	?	1	May-03		Folder 1
Real Time Viz of Urban Landscapes using open-source software	www.	Martin Kada et al	2	May-03		Folder 1
MultiGen-Paradigm - Urban Solutions	www.multigen-paradigm.com/solutions/urban/cerritos.3html		2	Dec-03		Folder 1
The City Goes Virtual	http://cebe.cf.ac.uk/learning/habitat/HABITAT2/vrtual.html	Aurigi, Alessandro. 1996.	1	Sep-04		ARCH VIZ
CAD for AEC principles	http://www.architectureweek.com/2000/0802/tools_3-1.html	Susan Smith, 2000	1	Sep-04		ARCH VIZ
Digital Cities And Urban Life. A framework for international benchmarking.	http://delivery.acm.org/10.1145/990000/984731/p9-einemann.pdf?key1=984731&key2=7527997211&coll=GUIDE&dl=GUIDE&CFID=55946	.Einemann, Edgar. Paradiso, Maria. 2004	1	Sep-05		
Dispersion Simulation and Visualization for Urban Security	http://delivery.acm.org/10.1145/1040000/1034492/87880553.pdf?key1=1034492&key2=8537997211&coll=GUIDE&dl=GUIDE&CFID=5594	Qiu, Feng. Zhao, Ye. Xiaoming, F 2004	1	Sep-05		
A Versatile Large-Scale Multimodal VR System for Cultural Heritage Visualization: CONFERENCE: VRST'06, Limassol, Cyprus.	http://portal.acm.org/citation.cfm?id=1180523&jmp=cit&coll=ACM&dl=GUIDE&CFID=15151515&CFTOKEN=6184618. Accessed 10th Februa	Chris Christou1, Cameron Angus1 Nov 1 - 3 2006	1			
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The Application Of 3d Modelling Techniques In Built Environment Evaluation.	http://www.rgu.ac.uk/files/laingdavieshargreavesscott2002.pdf.	Laing , Richard, Davies, Anne-Mar 2002	1	Mar-07		
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The CAD Manager Survey 2006 results	http://216.239.59.104/search?q=cache:lx4mV266LXsJ:www.eatyourcad.com/dl.php/Evolve-CADSurvey2006.pdf . Accessed 12th April 2007	Davies, Nigel 2006	1	April 12 2007		

Visualisation and VR Literature Review

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Three Dim computation Vis for comp graphics rendering Algorithms		David A. Goldman et al				3	01 November 2003		Folder 1
3-D Speaks Volumes	Computer world	Kay Russell	01/01/2002	vol 36 issue 14	44	3	01 November 2003	3D viewed on a 2D screen	Folder 1
All eyes on CAD	Computer Graphics World	Diana Phillips Mahoney	01/05/1999	Vol 22 Issue 5	38	10	01 November 2003	Quote: 3D Animation	Folder 1
Visual Modelling: From images to images	The journal of Viz and Comp Animation	Mac Pollefeys + Luc Van Gool	2002	Vol 13	199-209	2	01 May 2002		Folder 1
A novel progressive modelling algorithm for 3D models	The journal of Viz and Comp Animation	S Yang, C Chang, D Duan M Lin	2002	vol 13	187-198		01 June 2002		Folder 1
3D or not 3D: Is it Nobler in the mind	People and Computers	Alistair Sutcliff & Uma Patel	1996		79 - 94	1	01 March 2004		Folder 1
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Why not make interfaces Better than 3D Reality?	IEEE Computer Graphics and Applications	B Shneiderman	Nov/Dec 2003	vol 23	12 to 13	3	01 January 2004	uote: better than the real thir	Folder 1
3D Reconstruction and Visualization	IEEE Computer Graphics and Applications	Bill Ribarsky and Holly Rushmeier	Nov/Dec 2003	vol 23	20-21	4	01 January 2004	Thoughts: Ponty Project	Folder 1
Sea of Images	IEEE Computer Graphics and Applications	Daniel Aliaga et, al	Nov/Dec 2003	vol 23	22 - 30	2	01 January 2004	Quote: Hand held devices	Folder 1
Information availability in 2D and 3D Displays	IEEE Computer Graphics and Applications	Harvey S. Smallman John, M. Oonk, H, Cowen, M	Sep-Oct 2001	?	51-57	4	01 February 2004		Folder 1
Analyzing real data in a Virtual World	The Leading Edge	Hanley, Samantha	Jun-99		710 - 712	1	01 August 2004		Folder 1
Virtual Reality as Communication tool: a socio-cognitive analysis	IOS Press, Amsterdam	Riva. G, Davide. F	2003		47-56	1	01 August 2004	Public Communication	Folder 1
Whats real about Virtual Reality?	IEEE Computer Graphics and Applications	Frederick P. Brook Jr	Nov/Dec 1999		16-27	1			
ASC Proceedings of the 27th Annual Conference Brigham Young University-Provo, Utah		Robert Segner, William McManus	April 18-20, 1991		183-192	1	01 August 2004	Lots written	Folder 1
Virtual Reality Technology in Architecture and Construction	ITcon	Kahkonen, K.	2003	Vol 8	101-103	1	01 August 2004		VIZ Folder
Ifc -Product Models For The Aec Arena	ITcon	Tarandi, V.	2003		pp 135	1	01 August 2004		VIZ Folder
Industrial Case Studies on the use of 4D CAD/VR Modelling.	Seminar at Architectural3D Head Office	et all	2004			6			
Multiple path-based approach to image-based street walkthrough.	Journal of Computer Animation and Virtual Worlds.	Lee, Dong Hoon. Jung, Soon Ki.	2005	Vol 16	85-95	1	01 September 2005		
Visualization in Urban Planning: They Didn't Build LA in a Day.	The Journal of Computer Graphics and Applications, IEEE.	Delaney, Ben.	VMay-June 2000	Vol 20, Iss 3,	Oct-16	1			
Computer-based visualization of forest management: A primer for resource managers, communities, and educators.	BC Journal of Ecosystems and Management.	Lewis, John. Sheppard, Stephen. Sutherland, Karyn.	2004	*vol 5, Issue 2.*	May-13	1			
Futurescapes	Journal of Computers, Environment and Urban Systems	Lovett, A.	May-05	Vol 29, Issue 3	249-253	1	04 Oct 05		
Representing climate change futures: a critique on the use of images for visual communication	Journal of Computers, Environment and Urban Systems	Nicholson-Cole, Sophie.	May 2005,	Vol 29, Issue 3	255-273	1	04 Oct 05		

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The Art of 3D computer animation and effects.	Wiley, New Jersey	Isaac V. Kerlow	Jun-04	1 and 3	3-33 + 81-85	1	38200		
Using Interactive Design System Based on Multimedia mixing in the Environmental Design Planning Stage.	Printed by Optima Grafische Communicatie, Rotterdam.	Oh, Sooyeon. Nezu, Akiko. Yeo, Wookhyun. Fukuda, T	Sep-05			1			
Visualization in Landscape and Environmental Planning: Visualization in Support of Public Participation.	Taylor and Francis. London.	Kwartler, Michael. 2005.	Jun-05			1			
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Visualization in Landscape and Environmental Planning: The Provision of Visualization Tools for Engaging Public and Professional Audiance	Taylor and Francis. London.	Miller, David. Morrice, Jane. Caleby, Alastor.	2005	8	175 - 183	1			
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Should we BIM? Pushing the state of the Art in AEC	www.cadenceweb.com/2003/0603/converstory0603.html		2	01/06/2003	What is BIM	Folder 1
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Bringing 2D CAD to life	www.cadserver.co.uk/common/viewer/archive/2002/Oct/23/feature3	?	1	01/06/2003		Flolder 1
Beyond the Realms of Design	www.cadserver.co.uk/common/viewer/archive/2002/Nov/12	?	2	01/06/2003		Folder 1
Real-Time 3D Model Acquisition	http://graphics.stanford.edu/papers/rt_model/rt_model.pdf	Rusinkiewicz et al [2002]	1	01/04/2004	Scanner	Folder 1
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Inside Reality: 3D Virtual Reality Technology	http://www.sis.slb.com/content/software/virtual/index.asp	Schlumberger	1	01/08/2004		Folder 1
Second Life	http://secondlife.com		1	01/08/2004	Living in a VR Worlds	Folder 1
The future of Virtual Reality	http://www.mud.co.uk/richard/vrfuture.htm	Bartle, Richard	1	01/08/2004		VIZ
Why do we need to Visualize	http://www.aapg.org/explorer/geophysical_corner/gpceditor.cfm	Alistair R. Brown	1	01/08/2004		VIZ
Virtual Reality	http://abcasiapacific.com/nexus/stories/s655971.htm		1	01/09/2004		VIZ
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Possibilities and Constraints of using Virtual Reality in Urban Design	1. http://80.110.251.60/corp/archiv/papers/2002/CORP2002_Araby.pdf	El Araby, M. 2002. Multimedia Plan 457-463.	1			ARC VIZ
Usefulness of CAVE and Fish Tank VR Display Systems for a Scientific Visualization Application	http://vis.cs.brown.edu/docs/pdf/Demiralp-2003-SUC.pdf	Demiralp, Cagatay. Laidlaw, David H. Jackson, Cullen. Keefe, Daniel. Zh	1	18th Sep 05	CAVE and Fish Tank	
Interactive Design of Multi-Perspective Images for Visualizing Urban Landscapes	https://graphics.stanford.edu/papers/multi-cross-slits/interactive-multi-x-slits.pdf	Levoy, Marc. Roman, Augusto and Garg, Gaurav.	1	19th sep 05		
Extraction of Topologically Simple Isosurfaces from Volume Datasets	http://www.cc.gatech.edu/fac/Andrzej.Szymczak/papers/extraction.pdf	Szymczak, Andrzej. Vanderhyde, James. Tech, Georgia	1	19th Sep 2005		
Expressive Virtual 3d City Models	http://cartesia.org/geodoc/icc2005/pdf/oral/TEMA15/Session%209/JUERGEN%20DOELLNER.pdf	Dollner, Jurgen. Buchholz, Henrik. 2005.	1	22nd Sep 2005		
Precise Lidar-Data - An Efficient Way To Build Up Virtual 3d City Models	http://lusigiob.edinfor.logicacmg.com/portal/docs/Lisbon_LHB_2004.pdf	Lohr, U. Hellmeier, A. Barruncho, L. 2004	1	22nd Sep 2005		
Modelling And Visualizing 3D Urban Environment Via Internet For Urban Planning And Monitoring	http://www.isprs.org/istanbul2004/comm2/papers/151.pdf	Zhou, Guoqing. Tan, Zhenyu. Cheng, Penggen. Chen, Weirong. 2004.	1	22nd Sep 2005		
Inside Reality	http://www.slb.com/media/services/software/virtual/inside_reality_techsheet.pdf	Schlumberger. 2005.		10th Oct 2005		
Rapid Based 3D modelling: Virtual Reality Software and Technology: Proceedings of the ACM symposium on Virtual Reality software and t	http://portal.acm.org/citation.cfm?id=1101616.1101646	Sebe, I. You, Suya, Neumann, U.	1	26th March 2006		

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The Parametric Building Modeller	CAD User Mechanical Magazine		*Nov-00*	Vol 13 No 10		1				REVIT

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Autodesk Revit 7	http://www.aecbytes.com/review/Revit7.htm	Khemlani, Lachmi. 2004.	1		14th March 2005.		REVIT
Building modeling software adds long-awaited API. Autodesk Revit 7.	http://aec.cadalyst.com/aec/article/articleDetail.jsp?id=133494	Goldberg. Edward. 2004.	1		14th March 2005.		REVIT
Autodesk Revit 6	http://www.aecbytes.com/review/Revit_6.htm	AECbytes Product Review (January 29, 2004)	1		14th March 2005.		REVIT
Revit - 2D or 3D?	http://cadserver.co.uk/common/viewer/archive/2005/Feb/11/news8.phtm	AECbytes	1		14th March 2005.		REVIT
Revit 7	http://cadserver.co.uk/common/viewer/archive/2004/ Dec/20/news5.phtm	Day, Martyn. AEC Magazine. Nov/Dec 2004	1		14th March 2005.		REVIT
Autodesk unveils Revit series	http://cadserver.co.uk/common/viewer/archive/2003/Dec/16/news1.phtm	Cadserver [2003]	1		14th March 2005.		REVIT
Revit and the future 4.5	http://cadserver.co.uk/common/viewer/archive/2002/Jun/25/feature22.phtm	Cadserver, [2002].	1		14th March 2005.		REVIT
Revit Revisited	http://cadserver.co.uk/common/viewer/archive/2001/Jun/7/feature1.phtm	Day, M. [2001].	1		14th March 2005.		REVIT
Revit offers alternative path for R14 users.	http://cadserver.co.uk/common/viewer/archive/2001/Jun/7/news4.phtm.	Corke, G. 2001.			14th March 2005		REVIT
Revit appoints first UK solutions provider	http://cadserver.co.uk/common/viewer/archive/2001/Jun/25/news2.phtm.	Cork, G, 2001b.			Accessed 14th March 2005		REVIT

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Automatic Generation of High-Quality Building Models from Lidar data	IEEE Computer Graphics and Applications	Franze Rottensteiner	Nov/Dec	Vol 23	42 - 50	3	Jan-04	Lidar Data	Folder 3
Constructing 3D City Models by Merging Aerial and Ground Views.	IEEE Computer Graphics and Applications	Christian Fruh,Avideh Zakhor	Nov/Dec	Vol 23	52 - 61	1	Jan-04	Useful for Urban Planning	Folder 3
Fast 3D Model Generation in Urban Environments	IEEE Computer Graphics and Applications	Christian Fruh,Avideh Zakhor	2001		165 - 170	1	Mar-04	Scanning	Folder 3

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Principles of Geographic Information Systems for Land Resources Assessment		Burrough, P.A	1986	Clarendon Pr	Oxford	2			
Towards n-Modelling in Urban Planning.	Proceedings of the 3rd International Conference on Innovation in Architcture, Engineering and Construction. Rotterdam, The Netherlands, 15 -17th	Tanyer, A. M. Ta, J.H. Aouad, G.	2005		Vol 2. pp 503 – 51	Optima Grafische Communicatie, Rotterdam.	Sep-05		

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Bentley and Esri announce AEC GIS Interoperbility Initiativre	http://www.bentley.com/corporate/media_room	Michelle Rudiman	6	Jul-03	eroperability of DWG and	Folder 3
Bentley and Esri Interoperability - White papers	www.bentley.com	Bentley March 2003	3	Jul-03	eroperability of DWG and	Folder 3
Bentley and Esri Interoperability in GIS Monitor	www.bentley.com/corporate/news	Tony Flynn Bentley chief marketing officer in	2	Jul-03	eroperability of DWG and	Folder 3
GIS Solutions - Mobile, desktop and enterprise integration	www.cadserver.co.uk/common/viewer/archive/2001/oct/31		5	Jul-03		Folder 3
3D GIS, where are we standing	http://www.gdmc.nl/zlatanova/thesis/html/refer/ps/st_zl_03.pdf	Jantien Stoter and Siyka Zlatanova	1	Aug-04		Gis
Adding 3D Visualisation Capabilities to GIS	http://www.casa.ucl.ac.uk/venue/3d_visualisation.html	Smith, Andy	1	Aug-04		
CAD, GIS Integration: Why Would You Want to Do This Anyway?	http://www.directionsmag.com/article.php?article_id=478&trv=1&PHPSESSID=9a26bddb8c4476e3f9aa59d53ae9bd91	Reid, Hal. 2003	1	Nov-04		GIS
Bridging the Worlds of CAD and GIS	http://www.directionsmag.com/article.php?article_id=601	Oosterom, Peter van. 2004	1	Nov-04		
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3D Data Acquisition and Object Reconstruction for AEC/CAD	http://www.directionsmag.com/article.php?article_id=628	Tao, Vincent. 2004.	1	Nov-04		
AEC FROM THE GROUND UP: CAD and GIS Integration	http://aec.cadalyst.com/aec/article/articleDetail.jsp?id=123115	Sipes, James L. 2004.	1	Nov-04		
Modelling For 3D GIS: Spatial Analysis And Visualisation Through The	http://www.gdmc.nl/zlatanova/thesis/html/refer/ps/sz_kt_ISPRS.pdf	Zlatanova, Siyka. Tempfli, Klaus. 2000	1	Sep-05		
The potential of public participation GIS in UK environmental planning:	http://www.casa.ucl.ac.uk/muki/pdf/Harrison_Haklay_JEPM2002.pdf.	Harrison, Carolyn. 2002.	1	26th Sep 05.		
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Increasing Understanding During Collaboration Through Advanced Representations	The Journal of ITcon.	Lottaz, Claudio.	Feb-00	Vol 5	Jan-24	1		OTHER SOFTWARE	
Future Of Product Modeling And Knowledge Sharing In The Fm/Aec Industry.	The Journal of ITcon.	Koyvu, Tapio.	Jul-02	Vol 2	139 - 156	1		OTHER SOFTWARE	

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Real-Time Rendering	www.cadserver.co.uk/common/viewer/archive/2002/Nov/12/feature16.phtm				December 18 2003	RTRE	Folder 2
Gis Connect	www.upfrontezine.com/upf-360.htm		Adena Schtzberg		December 18 2003	Gis	Folder 2
A new Cad/Gis Solution	www.gismonitor.com/news/newsletter/archive/101603.php			1	December 18 2003	Gis	Folder 2
Artlantis Overview	http://www.abvent.com/us/software/artlantis						
Accelerated learning in a digital information environment	http://www.kb.com.au/downloads/Accelerated%20learning%20in%20a%20digital%20information%20environment.pdf	Karen Bonanno	2000		Used in Article 3		
Ordnance Survey Framework document	http://www.ordnancesurvey.co.uk/oswebsite/aboutus/reports/frameworkdocument2004.pdf		Jul-04		Nov-11		None
CAD Manager: CAD Manager Survey 2004, Part 2: Is the 3D software revolution under way yet?	http://management.cadalyst.com/cadman/article/articleDetail.jsp?id=139981&searchString=software%20survey.	Green, Robert	2004		Accessed 13th August 2006		
CAD Manager: CAD Manager Survey 2005, Part 1: Readers reveal popular CAD software options and more	http://management.cadalyst.com/cadman/article/articleDetail.jsp?id=282579&searchString=software%20survey%202005.	Green, Robert	2005		Accessed 13th August 2006		
3D Studio Max	http://www.cebe.ltsn.ac.uk/learning/habitat/HABITAT4/3d_studio_max.html		Knight, Mike. 1997. [On-line HABITAT Issue 4: July 1997]	1	Sep-04		3D MAX
Virtual Reality Modeling Language	http://www.bae.ncsu.edu/research/blanchard/www/465/textbook/otherprojects/1999/Virtual_Reality/group3/allen/apps-intro.html		Pete Ardrey	1		May-04	

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Consensus on Control	Changing the Culture (ODPM Supplement in association with Planning)		38047	?	5	1	Apr-04	Community involvement	
Virtual Reality Spotlights Valley Regeneration Plans.	The Journal News Paper	UNKNOWN	38196			1			
3-Dimensional RR in Urban Management	Photogrammetry, Remote Sensing and Spatial Information Sciences	Bhunua, S. T. Ruthera.H and Gainb, J.	38504	Vol. XXXIV.	Part 6/W6	1			
Visualising the potential impacts of climate change on rural landscapes.	The Journal of Computers, Environment and Urban Systems	Dockerty, Trudie. Lovett, Andrew. Sünnenberg, Billa. Appleton, Katy. Parry, Martin.	2005	Vol 29, Issue	May 2005, Pages 297-320	1	Oct-05		
GIS-based visualisation of development proposals: reactions from planning and related professionals.	The journal of Computers, environment and Urban Systems	Appleton, Katy. Lovett, Andrew.	2005	Vol 29, Issue 3	May 2005, Pages 321-339	1			
Integrating GIS, simulation models, and visualization in traffic impact analysis.	The journal of Computers, environment and Urban Systems	Wang, Xinhao.	2005	Vol 29, Issue 4	July 2005, Pages 471-496	1			
GIS-based visualisation of development proposals: reactions from planning and related professionals.	The journal of Computers, environment and Urban Systems	Appleton, Katy. Lovett, Andrew.	2005	Vol 29, Issue 3	May 2005, Pages 321-339	1			
Remote sensing for urban analysis: An introduction.	The journal of Computers, environment and Urban Systems	Yang, Xiaojun.	2005	Vol 29, Issue 5	Sep 2005, Pages 497-500	1			
Model Objects--a model management component for the development of planning support systems.	The journal of Computers, environment and Urban Systems	Yeh, Anthony. Qiao, Jimmy.	2005	Vol 29, Issue 2	March 2005, Pages 133-157	1			

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The Livable City: Revitalizing Urban Communities	McGraw-Hill. Washington	McNultry, Robert H	2000	1		1	Oct-04	Community involvement	URBAN
Neighbourhood Regeneration: Resourcing Community Involvement.	The Policy Press. Bristol	Duncan, Pete and Thomas, Sally	2000	1,2,3,4		8	**Oct-04**	Community involvement	URBAN
Relationship Appraisal of High-Rise Housing Estates	The R Foundations	Caroe, Ruth	19 95	Appendix 1	37-43	1		Community involvement	URBAN
Urban Research Summary.	ODPM Publishers. London	ODPM	2003		01-Mar	1	25th April 2005		URBAN
Visualization in Landscape and Environmental Planning: Communication, Perception and Visualization.	Taylor and Francis. London.	Lange, Eckart. Bishop, Ian.	2005			1			
The use of visualization technologies for the integration of building end-user perspectives, a managerial approach. Proceedings of the 3rd International Conference on Innovation in Architecture, Engineering and Construction.		Carvajal, Alejandro.	2005			1	Sep 28th 2005		
Visualization in Landscape and Environmental Planning: Validity, Reliability and Ethics in Visualization.	Taylor and Francis. London.	Sheppard, Stephen.	2005	5	79 - 98	1	Sep 28th 2005		
Results that matter : improving communities by engaging citizens, measuring performance and getting things done.	[U.S.] : John Wiley Publishers	Epstein, Paul D	2006	1	1	1	26th Oct 2006		
Visualization in Landscape and Environmental Planning: Visualization and Participatory Decision Making.	Taylor and Francis. London.	Perkins, Nathans. Barnhart, Steve.	2005	10	241 - 250	1	Sep 28th 2005		
Town and Country Planning	Routledge Taylor and Franis Group. London	Cullingworth, Barry and Nadin, Vincent	2006	1 and 12	12 and 432	1	Sep 22nd 2005		

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Title of Article	Web Address	Written by	Quotes	Accessed/Read	About	Find
Course Details at Sheffield University	www.shu.ac.uk/schools/urs/pgersur.htm	Steve Crocker	5	Dec-03		Folder 3
Virtual Cities Taking Shape In Research At RGU	http://www.rgu.ac.uk/news/disp_NewsPreview_text.cfm?pge_id=8274&vmenu=4&SubSection=activity	Laing, Dr Richard. 2003	1	Sep-04		URBAN
Architectural Visualisation- Virtual Cities	http://www.cpa.ed.ac.uk/pressarchive/05.1999-VISAGE.html		1	Sep-04		URBAN
	http://www.port.ac.uk/departments/academic/architecture/research/	McCartney, K. 2004	1	Sep-04		URBAN
Realism in modelling the Built Environment on the World Wide Web	http://cebe.cf.ac.uk/learning/habitat/HABITAT4/smith.html	Smith, Andrew. 1997.[On-line Habitat Issue 4 July 1	1	Sep-04		URBAN
About Sure Start	http://www.surestart.gov.uk/aboutsurestart/	?	1	Oct-04		URBAN
Urban Regeneration.	http://www.wda.co.uk/index.cfm/working_with_your_community/property_and_infrastructure/urban_regeneration/en117	WDA 2004	1	Nov-04		URBAN
Regeneration in Wales.	http://www.justdosomething.net/xsp/xsc.asp?uri=/home/hsw/regen/wales.	Common Purpose. 2004. Julia Middleton	1	Nov-04		URBAN
Objective 1	http://www.merthyr.gov.uk/Home/Regeneration/External+Funding/Objective+1+Funding/			Nov-04		URBAN
West Wales And The Valleys Objective One Programme 2000-2006 Annual Implementation Report 2003	http://www.wefo.wales.gov.uk/resource/Obj1_AIR2003_MainDoc4179.pdf.			Mar-05		NONE
Searching for Solid Foundations: Community Involvement and Urban Policy	Ohttp://www.odpm.gov.uk/stellent/groups/odpm_planning/documents/page/odpm_urbpol_023886.pdf.	ODPM. 2004.	1	25th April 2005.		URBAN
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Community Involvement in planning: The Governments Objectives	http://www.odpm.gov.uk/stellent/groups/odpm_planning/documents/page/odpm_plan_027497.pdf.	ODPM. 2004c.	1	25th April 2005.		URBAN
Gordon's BIG Breakfast	http://www.newstartmag.co.uk/spending.html.	Dobson, Julian and West, Tim. 2005	1	24th June 2005		URBAN
Computer Modelling and local governance: challenges for "citizen science"	http://www.york.ac.uk/inst/sei/pp/computer%20modelling.pdf.	Forrester, J and Cinderby, S. 2002.	1	24th June 2005		URBAN
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Survey Analysis Literature review

JOURNALS

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Measuring the attitudeds of the g public via internet polls:	International Journal of Market R	Nick Sparrow and John Curtice	07/01 2004	46	23-44	1			
Stratified Sampling	Natural Resource Biometrics	David R. Larsen	15/10 2000			1	www.snr.missouri.edu/natr211		
Architectural Practices And Their Use Of It In The Western Cape Province, South	The Journal of ITcon.	Arif, Azza and Karam, Aly.	Sept 2001.	6	17-33	0	Saved copy		

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Title of Book	Publisher	Written by	Date	Chapter	Page	Quotes	Accessed/Read	About	Find
Introduction to Quantitative Research Methods	SAGE Publications	Mark Balnaves & Peter Caputi	2001	4	?	1	10/05/2004		
Small-scale Evaluation	SAGE Publications	Colin Robson	2000	1	7	1	10/05/2004		
Doing Qualitative Research	SAGE Publications	David Silverman	2003	1		1	10/05/2005		
Research Methods	Arnold	Edited by Tony Greenfield	1996	1 and 15		1	10/05/2004		
		Thomas 1996				1			
Asking Questions. [cited in Sapsford. R et la. Data Collection and Analysis]	SAGE Publications	Wilson M	1996	4	94	1	27/04/2005		
Qualitative Research and Evaluation Methods	SAGE Publications	Patton, M	2002	7	339-348	1	27/04/2005		
Survey Research Methods. Third edition	SAGE Publications	Fowler, Floyd	2002	5	93	1	16/09/2005		
How to conduct Surveys: A step-by-step guide	SAGE Publications	Fink, Arlene. Kosecoff, Jacqueline.	1985	2	25-40	1	16/09/2005		

WEB PAGES

Title of Article	Web Address	Written by	Quotes	Accessed/Read	About	Find
Internet Access	http://www.statistics.gov.uk/CCI/nugget.asp?ID=8&Pos=5&ColRank=2&Rank=128	National Statistics 27 April 2004 at 9	1	May-04		
Quantitative Research design	http://www.sportsci.org/jour/0001/wghdesign.html	Will G Hopkins 2000	1	May-04		
Selecting Which Basic Research Methods to Use	http://www.mapnp.org/library/research/slctng.htm	Written by Carter McNam 1999	1	May-04		
Quantitative or Qualitative Research?	http://www.audiencedialogue.org/qualiquant.html	Dennis List 24th of Feb 2004	1			
Questionnaire Design and Survey Sampling	http://home.ubalt.edu/ntsbarsh/stat-data/Surveys.htm#rssm	Professor Hossein Arsham	1	aunched on 2/18/1994, revised on a yearly basis.		
Stratified Sampling	http://www.ryerson.ca/~mjoppe/ResearchProcess/StratifiedSampling.htm	?	1			
Green CAD and 3D Design Survey	www.designcommunity.com/cgi-bin/mlk?http://www.ArchitectureWeek.com/2000/0712/tools_2-2.html	Thomas P. Conlon 2000	1	September 7, 2004		
The AEC Building Design Practice Study had over 580 participants.	http://www.geopraxis.com/	2001	1	September 7, 2004		
Questionnaire Design						
	http://www.cc.gatech.edu/classes/cs6751_97_winter/Topics/quest-design/	1997	1	16/09/2005		

Appendix 2

A copy of the Full questionnaire sent to BDPs in Wales and Information Sheet

Information Sheet One

The questionnaire attatched to this information sheet has been created as a tool for a specific aspect of my MPhil/PhD research project, which I am undertaking in the School of Technology, at the University of Glamorgan.

The aims of the research are:

- To identify suitable 3 Dimensional Building Information Modelling and Visualisation (3D BIMV) computer packages for the general public to visualise urban re-generation within their community, using some of the leading software solutions (classified as group 1), and compare with a number of emerging software solutions (classified as group 2).
- To examine the interface between GIS and Visualisation techniques to identify efficient modes of data sharing/ transfer, and obstacles that might need to be addressed
- To examine the attitudes of lay-people and professionals toward a computer generated model of existing buildings and proposals for urban re-generation projects in their community created with each of the software packages.

The aims of this postal questionnaire survey are:

- To identify how many architectural design professionals in Wales utilise 3 Dimensional Building Information Modelling and Visualisation (3D BIMV) computer packages as a design tool, and which packages prove to be the most popular, and why.
- To identify any current problems which architectural design professionals have encountered using the identified 3D BIMV software packages.

Confidentiality

I acknowledge that the information obtained from the questionnaire attached to this information sheet will be treated in the strictest of confidence, and it will not be used in the public domain without anonymity. The content of the questionnaire will be used for academic research purposes by me, as part of my Mphil/PhD, and if any of the findings of this research are published there will be complete anonymity for all data.

Please tick/circle, or write the response to each question. Do not feel obliged to answer questions, if you do not wish to do so.

1. County/Town/City of Residence__________________ **2. Gender:** (a) Male ____ (b) Female ____

3. Age: 16-20 21-24 25-29 30-34 35-39 40-44 45-49 50-54 55-59 60+

4. Title within Company: Architect_____ Designer_____ Building Consultant_____ CAD Manager/Leader_____
CAD Technician____ Surveyor____ Engineer____ Interior Designer____ Other____________________

5. Do you use computer aided modelling software, 2D or 3D, in your work? Yes____ No____

If you answered 'No' to question 5, please go to Question 16.

6. Which type of buildings do you use computer aided modelling software with? Residential____ Industrial____Commercial____ Educational____ Other______________________________

7. Do you work mainly in 2D and produce mainly 2D outputs? Yes____ No____***If you answered 'No' to question 7, please skip question 8, and go to Question 10. If you answered yes, answer question 8 and 9 then proceed to question 18.***

8. For what purpose do you use 2D CAD? Planning Applications____ Space Planning____ Refurbishment____ Extensions____ Concept design____ Detailed design____ Project management____Other______________

9. If you only use 2D CAD, would you consider using 3D modelling software? Yes____ No____

Please fold, and tuck behind address.

EMMAJANE MANTLE
UNIVERSITY OF GLAMORGAN
DIVISION OF THE BUILT AND NATURAL ENVIRONMENT
School of Technology
FREEPOST CR2486
University of Glamorgan
Treforest
Pontypridd
CF37 1GZ

Please fold, and tuck behind address.

---

10. For what purpose do you use 3D CAD? Planning Applications____ Space Planning____ Refurbishment____ Extensions____ Concept design____ Detailed design____ Project management____ Visualising design ideas to

i) Clients____ ii) other consultants____ iii) public____ iv) contractors____ v) sponsors____ Other__________

11. Which computer package(s) do you use (tick all that apply for 3D): *(a)* AutoCAD____ *(b)* ArchiCAD____
(c) Revit______ *(d)* Microstation______ *(e)* 3D StudioViz______ *(f)* 3DStudioMax______ *(g)* TurboCAD____ *(h)* Vectorworks_____ *(i)Floor Plan*______ *(j)* Other______________________________

12a. Do you use any additional add-on packages for your chosen software? Yes____ No____

12b. Which add-on packages? *(k)* Artlantis____ *(l)* Architerra____ *(m)* Accurender____ *(n)* Cinema4D____
(o) Softlogic____ *(p)* Photoshop____ *(q)* Photo-Delux____ *(r)* Corel Draw____ *(s)* Others ______________

13. How do you rate the software that you use from the following responses (insert the letters for all the chosen software from your responses to question 11/12b; V = Very)?

- **2D Design:** V. Good_______ Good_______ Indifferent_______ Bad________ V. Bad________
- **Ease of use:** V. Good_______ Good_______ Indifferent_______ Bad________ V. Bad________
- **Print/Plot setup:** V. Good_______ Good_______ Indifferent_______ Bad________ V. Bad________
- **Toggle 2D to 3D:** V. Good_______ Good_______ Indifferent_______ Bad________ V. Bad________

- **Visualisation:** V. Good________ Good________ Indifferent________ Bad________ V. Bad________
- **3D Realism:** V. Good________ Good________ Indifferent________ Bad________ V. Bad________
- **Walkthroughs:** V. Good________ Good________ Indifferent________ Bad________ V. Bad________
- **Compatibility:** V. Good________ Good________ Indifferent________ Bad________ V. Bad________

14. Have you encountered any problems with the software identified in question 12 and 13? Yes____ No____

15. If your answer was yes to question 14, please state the problems that you have experienced (insert the letters for all the chosen software from your responses to question 11/12b)?:____

____

____

16. In your opinion, do you believe that producing 3D Visualisation Images to convey information of a proposed urban-regeneration project to potential clients, council members, and members of the general public, would/does assist in the design and construction process, and acceptability of completed projects? Yes____No___

17. Please give your reasons to your response in question 18?____

____

____

____

18. Could you be persuaded to start using, or to change your current 3D modelling Software? No________

Yes, but only if the following were improved/included: ____**(insert the letters for all the chosen software from your responses to question 11/12b; S = Strongly)?**

- **2D Design:** S. Agree______ Agree______ Indifferent______ Disagree______ S. Disagree______
- **Ease of use:** S. Agree______ Agree______ Indifferent______ Disagree______ S. Disagree______
- **Print/Plot Setup:** S. Agree______ Agree______ Indifferent______ Disagree______ S. Disagree______
- **Toggle 2D to 3D:** S. Agree______ Agree______ Indifferent______ Disagree______ S. Disagree______
- **Visualisation:** S. Agree______ Agree______ Indifferent______ Disagree______ S. Disagree______
- **3d Realism:** S. Agree______ Agree______ Indifferent______ Disagree______ S. Disagree______
- **Walkthroughs:** S. Agree______ Agree______ Indifferent______ Disagree______ S. Disagree______
- **Free Training:** S. Agree______ Agree______ Indifferent______ Disagree______ S. Disagree______
- **Literature:** S. Agree______ Agree______ Indifferent______ Disagree______ S. Disagree______
- **Reduced Price:** S. Agree______ Agree______ Indifferent______ Disagree______ S. Disagree______

Further work

A further study as part of the MPhil/PhD research project will be to use the results from questionnaire 1 to model/visualise an existing building/s with both group 1 and group 2 software, in a UK town, which is currently undergoing urban re-generation. Part of this study will be gauge the opinions of current users of the group 1 and group 2 software, towards the urban re-generation model. Therefore, if you do not mind taking part in this further study, please complete your details below.

Surname:________________ **Initials**_____ **Title (Dr, Mr, Mrs, Miss, Miss)**______ **Email address**________________________

Address____

THANK YOU FOR TAKING THE TIME TO COMPLETE THIS QUESTIONNAIRE

Signature________________________ **Date**________________________

Appendix 3

An Example of the Full Questionnaire handed out during the Exhibition

Survey No._____

Please copy Survey number to each sheet

GENERAL QUESTIONS (Please answer before viewing the presentation.)

This presentation has been held to display the different ways of showing proposed future developments to members of the general public. The outcome of this presentation and questionnaire will help show which method is favoured by the general public.

Thank you for taking the time to participate in my research.

Please follow the instructions in each section, before answering the questions.

INTRODUCTION

Please complete Section 1 before viewing the presentation, by ticking/circling the appropriate response. (Please tick appropriate box)

1. Gender: Male [ ] Female [ ]

2. Age: [10-19] [20-29] [30-39] [40-49] [50-59] [60-69] [70+]

3. Occupation: [Clerical] [Management] [Technical / IT] [Professional] [Administrative] [Sales / Support] [Unemployed] [Student] [Retired]] [Other]

4. Do you live in the Pontypridd Area? Yes [ ] No [ ]

5. If yes, how many years have you lived in the Pontypridd Area?_______

6. How familiar are you with the Pontypridd Area?

   Very Familiar [ ] Fairly Familiar [ ] Not Familiar [ ]

7. How familiar are you with the decision to build on the car park adjacent to St Catherine's Church, named the St Catherine's Corner development?

   Very Familiar [ ] Fairly Familiar [ ] Not Familiar [ ]

8. What is your current opinion of the St Catherine's corner development?

   I strongly agree the development [ ] I agree with the development [ ]
   I disagree with the development [ ] I strongly disagree with the development [ ]

9. Do you participate in any local Planning events?

   Often [ ] Sometimes [ ] Rarely [ ] Never [ ]

Survey No.______

2D PLANS AND ELEVATIONS

1. Is this your

1st	2nd	3rd	4th	5th

table visited?

Please circle the appropriate number.

2.

Circle the appropriate Number	Very Easy	Easy	Not Very Easy	Difficult	Not very difficult	Not Sure
In your opinion, how easy is it to imagine what the **building will look like** from the 2D Plans and Elevations?	[1]	[2]	[3]	[4]	[5]	[6]
In your opinion, how easy is it to imagine the **size of the building** in comparison to other buildings around the site, from the 2D Plans and Elevations?	[1]	[2]	[3]	[4]	[5]	[6]
In your opinion, how easy is it to imagine how the **finishes will look** on the proposed building from the 2D Plans and Elevations	[1]	[2]	[3]	[4]	[5]	[6]

3. On a scale of 1 to 5, how effective is this form of presentation in regards to presenting information to the general public?

Very Effective	Effective	Not Very Effective	Very Ineffective	Not Sure
1	2	3	4	5

3. In your opinion, can these drawing be improved to convey a greater understanding?

Yes [ ] No [ ]

4. If yes, how, in your opinion can these drawings be improved?

____

____

____

HAND MADE MODEL

1. Is this your

1st	2nd	3rd	4th	5th

table visited?

Please circle the appropriate number.

2.

Circle the appropriate Code	Very Easy	Easy	Not Very Easy	Difficult	Not very difficult	Not Sure
In your opinion, how easy is it to imagine what the **building will look like** from the Hand Made Model?	[1]	[2]	[3]	[4]	[5]	[6]
In your opinion, how easy is It to imagine the **size of the building** in comparison to other buildings around the site from the Hand Made Model?	[1]	[2]	[3]	[4]	[5]	[6]
In your opinion, how easy is it to imagine how the **finishes will look** on the proposed building from the Hand Made Model?	[1]	[2]	[3]	[4]	[5]	[6]

3. On a scale of 1 to 5, how effective is this form of presentation in regards to presenting information to the general public?

Very Effective	Effective	Not Very Effective	Very Ineffective	Not Sure
1	2	3	4	5

4. In your opinion, can this model be improved to convey a greater understanding?

Yes [ ] No [ ]

5. If yes, how, in your opinion can this model be improved?

____

____

____

____

ARTISTS IMPRESSION

1. Is this your

1st	2nd	3rd	4th	5th

table visited?

2.

Circle the appropriate Code		Very Easy	Easy	Not Very Easy	Difficult	Not very difficult	Not Sure
In your opinion, how easy is it to imagine how the **building will look** from the Artists Impressions?	Image 1	[1]	[2]	[3]	[4]	[5]	[6]
	Image 2	[1]	[2]	[3]	[4]	[5]	[6]
	Image 3	[1]	[2]	[3]	[4]	[5]	[6]
In your opinion, how easy is it to imagine the **size of the building** in comparison to the other buildings around the site from the Artists Impressions?	Image 1	[1]	[2]	[3]	[4]	[5]	[6]
	Image 2	[1]	[2]	[3]	[4]	[5]	[6]
	Image 3	[1]	[2]	[3]	[4]	[5]	[6]
In your opinion, how easy is it to imagine how the **Finishes will look** on the proposed building from the Artists Impressions?	Image 1	[1]	[2]	[3]	[4]	[5]	[6]
	Image 2:	[1]	[2]	[3]	[4]	[5]	[6]
	Image 3:	[1]	[2]	[3]	[4]	[5]	[6]

3. On a scale of 1 to 5, how effective is this form of presentation in regards to presenting information to the general public?

Very Effective	Effective	Not Very Effective	Very Ineffective	Not Sure
1	2	3	4	5

5. In your opinion, can these drawings be improved to convey a greater understanding?

Yes [ ] No [ ]

5. If yes, how, in your opinion can these drawings be improved?

Image 1:______________________________

Image 2:______________________________

Image 3:______________________________

STILL IMAGES

1. Is this your

1st	2nd	3rd	4th	5th

table visited?

2.

Circle the appropriate Code	Very Easy	Easy	Not Very Easy	Difficult	Not very difficult	Not Sure
In your opinion, how easy Is it to imagine what the **building will look** like from the Still Images?	[1]	[2]	[3]	[4]	[5]	[6]
In your opinion, how easy is it to imagine the **size of the building** in comparison to other buildings around the site from the Still Images?	[1]	[2]	[3]	[4]	[5]	[6]
In your opinion, how easy is it to imagine how the **finishes will look** on the proposed building from the Still Images?	[1]	[2]	[3]	[4]	[5]	[6]

3. On a scale of 1 to 5, how effective is this form of presentation in regards to presenting information to the general public?

Very Effective	Effective	Not Very Effective	Very Ineffective	Not Sure
1	2	3	4	5

4. In your opinion, can these Images be improved to convey a greater understanding?

Yes [ ] No [ ]

5. If yes, how, in your opinion can these images be improved?

____

____

____

____

ANIMATION

1. Is this your

1st	2nd	3rd	4th	5th

table visited?

2.

Circle the appropriate Code	Very Easy	Easy	Not Very Easy	Difficult	Not very difficult	Not Sure
In your opinion, how easy Is it to imagine what the **building will look** like from the Animation?	[1]	[2]	[3]	[4]	[5]	[6]
In your opinion, how easy is it to imagine the **size of the building** in comparison to other buildings around the site from the Animation?	[1]	[2]	[3]	[4]	[5]	[6]
In your opinion, how easy is it to imagine how the **finishes will look** on the proposed building from the Animation?	[1]	[2]	[3]	[4]	[5]	[6]

3. On a scale of 1 to 5, how effective is this form of presentation in regards to presenting information to the general public?

Very Effective	Effective	Not Very Effective	Very Ineffective	Not Sure
1	2	3	4	5

4. In your opinion, can the Animation be improved to convey a greater understanding?

Yes [ ]   No [ ]

5. If yes, how, in your opinion can the Animation be improved?

____
____
____
____

GENERAL QUESTIONS (Please answer once all tables have been visited and a questionnaire sheet completed for each.)

1. Now that you have viewed the different presentation techniques, in your opinion which method did you find the most useful, and the least useful in conveying understanding of the proposed development? Using each number from 1 to 5 once, note which method you found most useful [1], to the least useful [5].

Section 1: 2D Plans and Elevations	[ ]
Section 2: Hand made models	[ ]
Section 3: Artist's impressions	[ ]
Section 4: Virtual reality animations	[ ]
Section 5: Realistic Still Images	[ ]

2. Please explain why you came to the above conclusion?

____
____
____
____
____
____
____
____

3. If a local planning event used the method chosen in question 9 above, would you participate more?

Definitely [ ]   Maybe [ ]   Unlikely [ ]   Definitely Not [ ]   Not Sure[ ]

As part of this project, we have made a video recording of you. We would like you to indicate (with ticks in the appropriate places) below what uses of these records you are willing to consent to. This is completely up to you. We will only use the records in ways that you agree to. In any use of these records, names will not be identified.

The records can be studied by the research team for use in the research project. [ ]

The records can be used for scientific publications and/or meetings. [ ]

The written transcript and/or records can be used by other researchers. [ ]

The records can be shown in public presentations to non-scientific groups. [ ]

The records can be used on television or radio. [ ]

Thank you for your time and participation in this research questionnaire. If you require any further information don't hesitate to contact Miss EmmaJane Mantle by post at the University of Glamorgan, School of Technology, CF37 1DL; by email at ejmantl1@glam.ac.uk.

Confidentiality: I acknowledge that the information obtained from the will be treated in the strictest of confidence, and it will not be used in the public domain without anonymity. The content of the questionnaire will be used for academic research purposes by me, as part of my PhD, and if any of the findings of this research are published there will be complete anonymity for all participants.

Appendix 4

An Example of the Shorter Questionnaire handed out during the Exhibition

GENERAL QUESTIONS (Please answer before viewing the presentation.) Please copy Survey number to each sheet

This presentation has been held to display the different ways of showing proposed future developments to members of the general public. The outcome of this presentation and questionnaire will help show which method is favoured by the general public.

Thank you for taking the time to participate in my research.

Please follow the instructions in each section, before answering the questions.

INTRODUCTION

Please complete Section 1 before viewing the presentation, by ticking/circling the appropriate response. (Please tick appropriate box)

2. Gender: Male [ ] Female [ ]

2. Age: [10-19] [20-29] [30-39] [40-49] [50-59] [60-69] [70+]

3. Occupation: [Clerical] [Management] [Technical / IT] [Professional] [Administrative] [Sales / Support] [Unemployed] [Student] [Retired]] [Other]

4. Do you live in the Pontypridd Area? Yes [ ] No [ ]

8. If yes, how many years have you lived in the Pontypridd Area?________

9. How familiar are you with the Pontypridd Area?

   Very Familiar [ ] Fairly Familiar [ ] Not Familiar [ ]

10. How familiar are you with the decision to build on the car park adjacent to St Catherine's Church, named the St Catherine's Corner development?

   Very Familiar [ ] Fairly Familiar [ ] Not Familiar [ ]

10. What is your current opinion of the St Catherine's corner development?

   I strongly agree the development [ ] I agree with the development [ ]
   I disagree with the development [ ] I strongly disagree with the development [ ]

11. Do you participate in any local Planning events?

   Often [ ] Sometimes [ ] Rarely [ ] Never [ ]

GENERAL QUESTIONS (Please answer once all tables have been visited and a questionnaire sheet completed for each.)

1. Now that you have viewed the different presentation techniques, in your opinion which method did you find the most useful, and the least useful in conveying understanding of the proposed development? Using each number from 1 to 5 once, note which method you found most useful [1], to the least useful [5].

Section 1: 2D Plans and Elevations	[ ]
Section 2: Hand made models	[ ]
Section 3: Artist's impressions	[ ]
Section 4: Virtual reality animations	[ ]
Section 5: Realistic Still Images	[ ]

2. Please explain why you came to the above conclusion?

____
____
____
____
____
____
____
____

3. If a local planning event used the method chosen in question 9 above, would you participate more?

Definitely [ ] Maybe [ ] Unlikely [ ] Definitely Not [ ] Not Sure[ ]

As part of this project, we have made a video recording of you. We would like you to indicate (with ticks in the appropriate places) below what uses of these records you are willing to consent to. This is completely up to you. We will only use the records in ways that you agree to. In any use of these records, names will not be identified.

The records can be studied by the research team for use in the research project. [ ]

The records can be used for scientific publications and/or meetings. [ ]

The written transcript and/or records can be used by other researchers. [ ]

The records can be shown in public presentations to non-scientific groups. [ ]

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Appendix 5

Publications

A SURVEY FOCUSING ON THE USE OF COMPUTER AIDED DESIGN AND 3D VISUALISATION BY UK BUILDING DESIGN PROFESSIONALS

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ABSTRACT: To identify the extent to which two and three dimensional computer aided design, modelling and visualisation software applications are used by building design professionals (BDPs) in the UK, with a focus on Wales. It is found that two dimensional computer aided design (2D CAD) software applications are still used predominantly by BDPs in the UK. However, there are BDPs who do use 3D CAD and 3D building information modelling, for a variety of projects.

KEYWORDS: Building Design Professionals, Two Dimensional (2D) Three Dimensional Computer Aided Design (3D CAD), Wales.

1. INTRODUCTION

Communication, is classed as "the exchange of thoughts, messages, or information, where the key emphasis is on the understanding of messages" [Kahkonen, 2003], suggesting that the main purpose of communication is to create understanding. The essence of ones understanding was accurately identified by Confucius (551-479 BCE) a chinees prophet, who said "What I hear I forget, what I see I remember, what I do I understand". Bonanno [2000] suggested that "we remember 20% of what we read, 30% of what we hear, 40% of what we see, 50% of what we say, 60% of what we do, and 90% of what we see, hear, say, and do". The medium used to communicate is therefore, an important aspect of any profession where public involvement needs to be considered.

In the building design professions (BDPs) where buildings and the environment in which they are positioned are being designed, showing relevant footage where interaction is attainable, can sometimes be difficult. Virtual Reality (VR) can be used to generate an interactive environment which can communicate ideas easily to viewers, as they are given the sense that they are fully immersed in the new development long before it has been created. It is however, an expensive visualisation tool and is therefore not always a feasible option for BDPs, such as Architects. Another, more feasible option is the use of Three Dimensional Computer Aided Design (3D CAD) and Three Dimensional Building Information Modelling and Visualisation (3D BIMV) software applications that allow the user to create and the viewer to explore a development or design via a computer monitor. Developments in 3D CAD and 3D BIMV packages could now play a vital role in conveying understanding to the viewer, such as a client or stakeholder.

The last decade has seen a "phenomenal growth in the use of computer technology" for BDPs [Arif et al, 2001], allowing professionals such as Architects and Engineers to design without the use of a drawing board, and to create crisper, more accurately dimensioned drawings by computers, where they can also be stored and edited. Drawings can be created with professional results, regardless of experience, the progression of new students in the field of 2D CAD is plainly visible in the author's lectures and there seems to be a natural ability for new students to easily adapt to the learning of new design software. The benefits are clear, and acknowledged by [Arif et al 2001] that "computer literacy reinforced by any CAD program knowledge is proven highly desirable among local practices". The use of 2D and 3D software in the building design process can be used to create drawings and models for a number of different purposes. For example, public consultation, planning applications, statutory approvals, documents for the tender process, and construction process. Whyte [2003] discusses that the use of 3D modelling has been available for the past ten years (1999 to 2003) and was disappointed when the results of her survey showed that "there is not one typical user of VR in the construction sector. It is consultant engineers, construction contractors and real estate owners, rather than architects that have made the largest investment in VR for the architectural design and construction of the built environment.

This paper will discuss the methodology used to survey BDPs in the UK (with a focus on Wales) and the CAD, modelling and visualisation packages they use in the building design process.

2. QUESTIONNAIRE DESIGN AND RESULTS

2.1 Questionnaire Design

In order to obtain information regarding which 2D or 3D CAD technology is being utilised by BDPs, a questionnaire was designed which included topics that would help build an understanding of what, and how the chosen software is being used. The survey was conducted in September 2003, and targeted BDPs, which included Architects, Interior Designers, Surveyors, Engineers, CAD Technicians and Property Developers. The author listed a total of 105 Architects, 120 Interior Designers, 97 CAD Technicians, 89 Engineers, 60 Surveyors and 96 Property Developers, using an internet based business finder, www.yell.com.

According to Thomas [cited in Greenfield, 1996] "A questionnaire should not be long and complicated." Considering this statement, the questionnaire was designed to be short and simple, succinct on double sided A4, with adequate space provided for open-ended questions, and for additional comments to be noted where needed. It contained both open-ended and closed-ended questions, which allowed the respondent to answer 'yes and no' questions, and to express an opinion, if desired, in relation to their current software and their attitudes on the advantages or disadvantages in using 3D images, and real time animation for the purpose of presenting designs. Questions of an open-ended nature were kept to a minimum and were only used to identify any issues relating to their current software, such as difficulty with its ease of use, and the opinions of the respondent regarding the use of 3D software applications within the building design process.

Before the questionnaires were sent to the BDPs a pilot study was undertaken with colleagues, which allowed for any ambiguities or problems with the questionnaire to be resolved before all 400 questionnaires were dispensed. As a result of the pilot study, some wording was changed to allow greater understanding for the reader, and additional questions were added to distinguish between the benefits and drawbacks, relating to the different software applications used by the respondent. The return address was also moved to the centre of the front page, so that only one fold was needed at both ends of the paper, where previously, it was located at the top of the page.

In August 2003, 400 questionnaires were dispatched to BDPs in Wales, and other areas of the UK, involved in the building design process.

2.2 Questionnaire Results

2.2.1 Response rate

A total of 400 companies were sent a questionnaire and 60 responses were achieved, giving a 15% response rate. The results from the questionnaires were divided into the six target groups discussed earlier. The coding and analysis process commenced with the coding being carried out in SPSS and the analysis in Microsoft Excel.

2.2.2 County/Town/City of Residence

The aim of this question was to establish the geographical location of the respondent where the highest percentage of respondents lived in Wales 78% (47). This was due to the fact that the focus of the research was on BDPs in Wales. Other responses came from England 17% (10), Scotland 2% (1) and Ireland 3% (2). Table1.1 below illustrates the location and company type of respondents.

Table 1.1: BDP type and Location.

BDP/ Location	BDP Type Architect	Interior Designer	CAD Technician	Property Development	Surveyor	Engineer
Wales	7	7	10	9	9	5
England	2	3	0	0	0	5
Scotland	0	0	0	1	0	0
Ireland	1	0	0	0	1	0

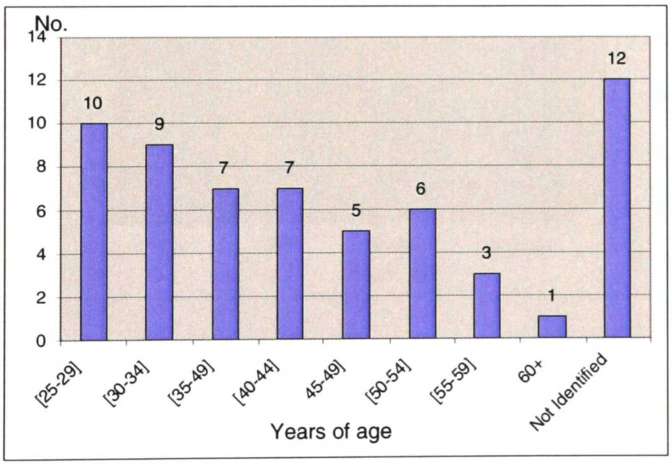
2.2.3 Gender

The second question was used to determine the gender of the respondent, the majority of which were male (68%). Furthermore the majority of Architect and Engineer respondents were respectively male (9, 90%), Interior Design respondents were mostly female (60%, 6). All CAD Technicians (100%, 10,) who responded and 60% (6) of Surveyors were also male.

2.2.4 Age of Respondent

Figure 1.1, below illustrates the age of BDP respondents, and it is seen that the youngest respondents work as Interior Designers and CAD Technicians. Asking this question helped to identify if there is a correlation between the age of the respondent and the software that is being utilised. Results illustrated in Table 1.2 below, shows that the majority of respondents, who currently use 3D software are Interior Designers. As it was demonstrated above, Interior Designers were also the youngest respondents. One interesting finding in relation to the respondents' age was that some of those who were in the 40 to 44 and above age category felt that 3D BIMV software tools were a very effective presentational tool, but were unable to use the software due to time restrictions for training and model generation.

Figure 1.1: Age of respondents in each target group.

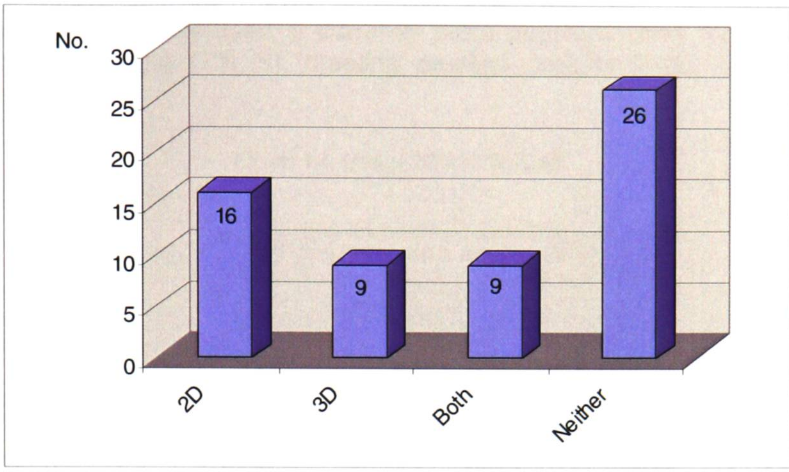


In discussions with each respondent, it was found that those below 40 years of age appeared to be more interested, and were more prepared to spare the time for personal development and training for 3D BIMV software.

2.2.5 Company Type

Figure 1.2 and Table 1.2 below, illustrates that the majority of respondents use 2D CAD software rather than 3D CAD and 3D BIMV.

Figure 1.2: The use of 2 or 3D



In addition, Figure 1.2 above illustrates that 43% (26) of the respondents used no form of software in the design process, which is surprising in the 21st century, and only 15% (9) were currently using 3D BIMV software. However Figure 1.3 shows that 34% (20) would consider using the software in the future, if prices were reduced.

Figure 1.3: Industries willing to use 3D

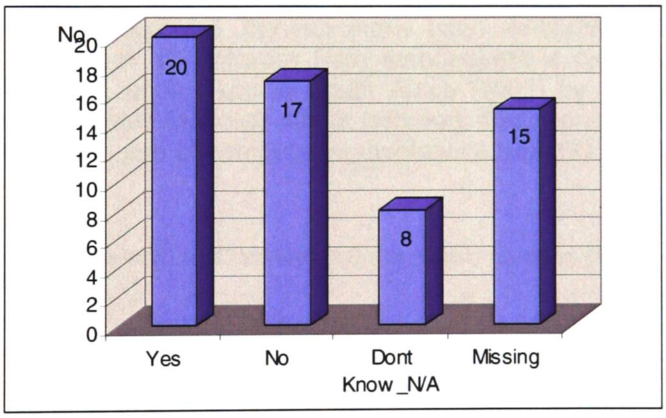


Table: 1.2 The use of 2 or 3D software in Building design process.

	Architect	Interior Designer	CAD Technician	Property Development	Surveyor	Engineer
2D	5	2	5	2	0	3
3D	2	4	0	0	1	2
Both	2	0	3	0	1	3
Neither	1	4	2	8	6	2

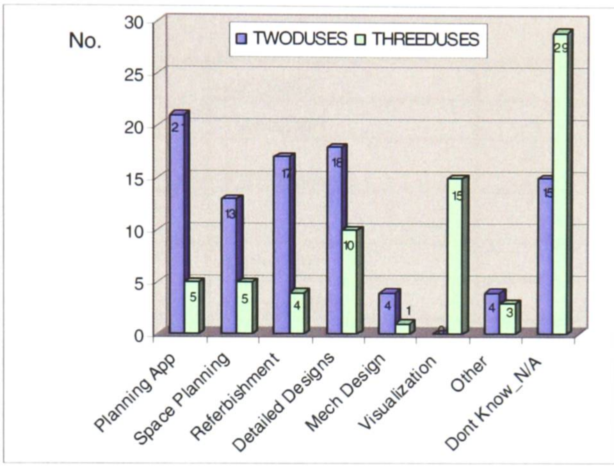
2.2.6 Production Type

This question aimed at establishing the areas in which the respondents worked, and the options included residential, industrial, commercial, education and other. Respondents worked across all industries.

2.2.7 General Use of 2D and 3D CAD

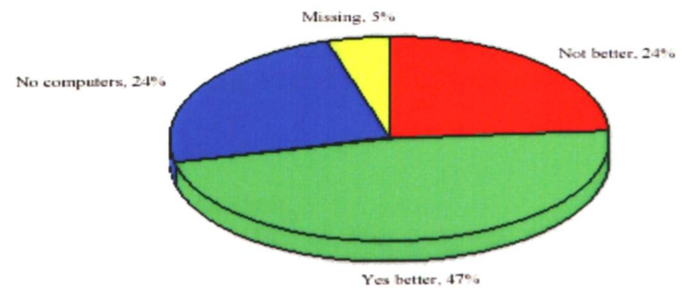
The analysed data showed that 23% (16) of the respondents are currently using 2D CAD to produce plans for proposed developments, as illustrated in Figure 1.4, and for planning applications 35% (21), detailed designs 30% (18), and refurbishments 28% (17). 3D CAD however, although not widely used is currently more popularly used for producing Interior spaces for space planning (7%, 5), creating detailed designs (14%, 10) and Visualizing projects (21%, 15).

Figure 1.4: Use of 2D and 3D CAD



From the 60 respondents taking part in this survey only 15% are currently using 3D software applications in their work. However most respondents could see the benefits of creating a 3D model for a proposed development, but not many have embraced such software. The prominent use, 21% (15), of 3D software from respondents is for visualising projects to clients. In a similar survey, undertaken in South Africa (2001) by Arif et al [2001], it was shown that 47% of companies in South Africa believed that a greater understanding of a project is conveyed with the use of computer presentations both 2D and 3D, as illustrated in Figure 1.5 below.

Figure 1.5 The use of 2D or 3D software in Building design process. [Arif et al 2001]



It is a pity that 3D software applications are not used by more BDPs in the UK, since from the author's experience this is what the public want. In another pilot study conducted in 2004, the author selected a small sample group of 20 individuals from a wide age group all familiar with a urban area in Wales, UK. The sample had no previous experience with reading 2D or 3D imagery, which allowed for a fair comparison to take place. The survey involved presenting each person with 8 images in both 2D and 3D. Each image was shown in turn until the correct location of the image was determined, by the respondent. The survey results showed that 90% of respondents could identify a 3D image, but only 10% could identify a flat 2D map of the same area.

2.2.8 2D and 3D Software applications

The survey showed that AutoCAD, a software application which can be used to create both 2D and 3D line drawings, was the most popular software adopted by the BDP respondents from the six target groups, with an overall percentage of 26% (17). In comparison the most popular 3D BIMV application was ArchiCAD, but with only 6% (4), as illustrated in Table 1.3 below.

Table 1.3: The use of 2D, 3D and rendering applications in building design professions.

2D Software	AutoCAD	17
	TurboCAD	1
	Vectorworks	1
3D BIMV	ArchiCAD	4
	Microstation	2
	Revit	0
	Allplan	0
Rendering And Modelling	3D Studio Max	5
	Cinema 4D	1
	3D Viz	2
Other	Other	10
	Dont Know/Not applicable	3
	None	19

The respondents using AutoCAD, were using it for its abilities to produce very high quality 2D plans, with exception for one engineering organisation from Wales who used the software to produce 3D images of furniture designs. This respondent believed that the production of 3D imagery is beneficial to their company, but suggested that "modern society rely on pretty pictures instead of solid facts." The "Other" software listed, were; UniGraphics, Metalsoft Fabriwin with a DXF Converter/Importer, Pro Engineer, Mechanical Stress analysis application and Lightscape.

2.2.9 Additional add-on applications.

The survey showed that 32% (19) of the targeted companies use add-on software applications, 55% (33) did not use any add-on applications, and 15% (8) did not give an answer. The most commonly used add-on application was Photoshop, used to manipulate images, with 47% (9). Other add-on software applications used were Corel Draw 5% (1), Artlantis 11% (2) a rendering application, Architerra 5% (1) used to create 3D terrain and highways. Table 1.4 below, illustrates in which companies add-on applications are being used, particularly the architectural organisations with 31% (9).

Table 1.4: The use of Add-on applications throughout the building design organisations.

	Architect	Interior Designer	CAD Technician	Property Development	Surveyor	Engineer
Atlantis	2	0	0	0	0	0
Architerra	1	0	0	0	0	0
Photoshop	6	2	0	1	2	1
Coral Draw	0	1	0	1	0	0
Other	0	1	3	0	1	2
Dont know/Not Applicable	1	7	6	9	4	6

2.2.10 Rating Chosen Software

This section of the questionnaire called for the respondents to grade their chosen software's ability to produce 2D images, ease of use, printing setup, toggling between 2D and 3D, visualisation, 3D realism, walkthroughs, and compatibility with other software.

From those who responded to this question (4, 7%) suggested that software had been chosen that most suited the company's requirements, at that current time. However if the companies developed, those who did not currently use 3D technology (42, 70%), would consider its use in future project. Some of the problems encountered by the BDP respondents in the use of 2D software i.e AutoCAD, related to importing and exporting files.

2.2.11 Respondents opinion towards 3D Technology.

The questionnaire concluded with an open-ended question requesting the respondents to provide their opinion of 3D computerised imagery, but only 32% (19) responded to this question. In relation to the use of 3D CAD respondents have noted that the use of 3D CAD allows lay-people to understand and contribute to designs, as it allows the untrained eye to get a sense of the finished environment and is viewed by some respondents as being of great advantage to all involved in the design process. However one respondent suggested that modern society relies on pretty pictures instead of solid facts. However, not all the BDPs who responded to the questionnaire considered that 3D CAD was an advantage. It seems that some respondents found the software difficult to use and it was suggested that the use of hand drawn images give a warmer and a friendlier appearance.

3. CONCLUSION

This paper set out to discuss what 2D or 3D software is being utilised by BDPs, and how it is being used. This questionnaire showed, in regards to the use of computer aided design, that 42% of the respondents are currently utilising computer technology within the building design profession. The youngest respondents, were CAD Technicians and Interior Designers, and were currently adopting the 2D and 3D method of computer imagery. The percentage of those currently adopting the use of 2D CAD only is 26% (16), 3D CAD only is 15% (9) and both is 15% (9).

Section 2.2.6 and onward discussed the different software currently being utilised by BDPs, and showed that AutoCAD and Photoshop proved to be the most popular software and add-on packages respectively, and from research undertaken by Whyte [2003] and Arif et al [2001] has shown that AutoCAD is the prominent software used not only in the UK, but in America, South Africa, Canada, Scandinavia, Denmark, Finland and Sweden.

It seems that over the past decade BDPs have embraced the 2D CAD method of presenting plans and elevations, however with the application of computer technology "moving forward with tremendous speed" [Arif et al, 2001], all industries and professions are being affected.

Arif [2001] would agree that computer use is extremely beneficial, stating that "Indications show that the technology is no more considered an excessive expensive luxury tool, but rather a necessity that offices are starting to invest in both human resources and in financial terms" [Arif et al, 2001].

The need for BDPs to use 3D software applications has also been confirmed in a pilot study undertaken on the general public in Wales, UK in 2004. The survey results showed that 90% of respondents could identify a 3D image, but only 10% could identify a flat 2D map of the same area.

The overall conclusion to this paper is that BDPs are still reluctant to embrace 3D software applications, particularly 3D BIMV, resulting in members of the general public having less opportunity to participate in developments, which may affect them.

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THE USE OF VISUALIZATION TO ENHANCE PUBLIC PARTICIPATION WITHIN THE PLANNING PROCESS

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ABSTRACT: This Research concerns the potential use of 3D Visualization within the planning process in the United Kingdom and addresses the issue of improving public participation within urban regeneration. The main focus of this research was to look at the different techniques currently available for presenting proposed regeneration projects to members of the general public, and distinguish, as a result of a survey, the techniques that are most favoured by participants. The research also investigated the readiness of the building design profession to offer 3D visualisations of such projects. A survey was undertaken of 3D computer aided design (3D CAD) software applications currently being utilised within the profession, evaluates the use of a range of 3D CAD software applications and investigates the possibilities of using Geographical Information System (GIS) software applications in conjunction with these CAD packages, as a means to produce accurate terrain data upon which to base new developments.

Keywords: urban regeneration, public participation, 3D Visualization

1 Introduction

"New buildings and spaces are created by architects, developers, planners and many other professionals. But they are made for the people who will use them – the resident, the pupil, the patient, the office worker, the parent in the park. All of our lives are intimately affected by the quality of the environment we inhabit. And, if we genuinely believe we are engaged in creating places for people, we have to put people centre stage" [Sorrell, 2005].

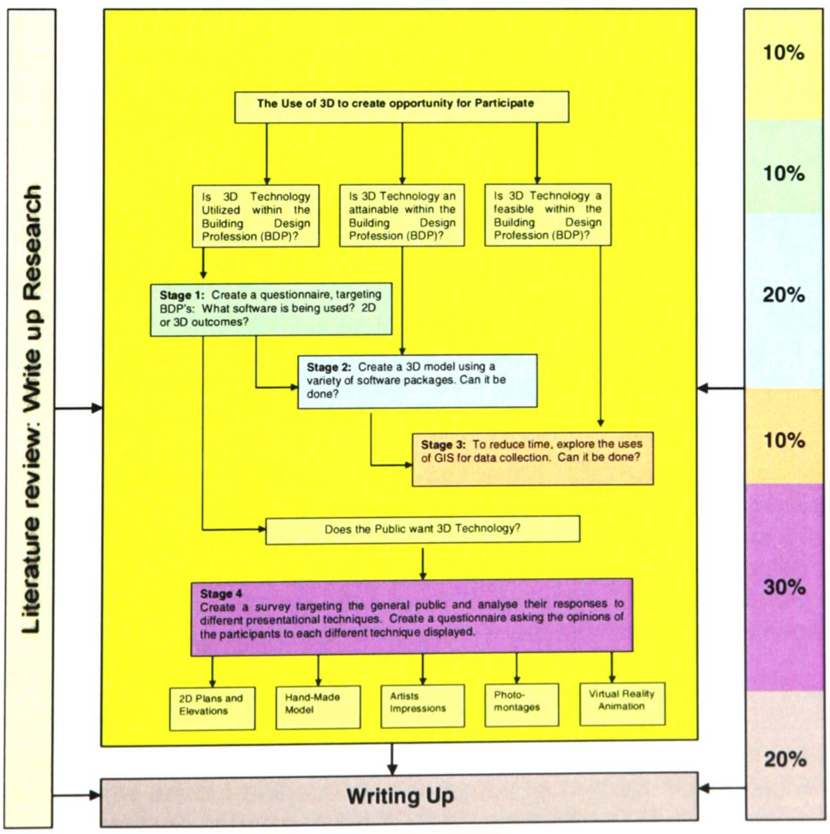
This research has looked at the importance of 3D Visualization within the planning process, and addresses the issue of improving public participation within urban regeneration. The focal point of this thesis is that the inclusion of public opinion should be normative in regards to the planning process and urban re-generation. At the outset it is recognised that there are a variety of problems associated with the issue of truly representing public opinion: for example defining 'public' or resolving disputes and ambiguities.

This research was not concerned with these aspects of public policy but is more specifically interested in a technical barrier to inclusion.
Current techniques used to display information about proposed developments are not always easy for members of the public to understand. Therefore, in addition, this research also discusses the different techniques currently available for presenting proposed regeneration projects to members of the general public, and aimed to distinguish, as a result of a survey the technique most favoured by the participants.
At present, the chief method of displaying proposed developments to the general public, 2D plans and elevations, does not give appropriate opportunities for participation. Smallman et al [2001] suggest that 3D imagery would spare the viewer the "mentally demanding process of scanning back and forth to integrate two planer views." The limitations of 2D depiction are well documented:

- The image is flat, the viewpoint is unique
- The image is finite
- The image is static
- The image has a limited contrast and gamut (MIT, undated)

In a 3D computer generated model "all three dimensions are continuously available and represented analogically as actual distances on the display" [Smallman et all 2001]. This research has looked at the importance of public participation within urban regeneration, and investigates whether 3D Visualization will help encourage more people to participate in planning events.

Below is a table which illustrates the stages this research has passed to reach its final conclusion.



2 Local Governments

Today, the government is putting a much greater emphasis on public participation "and there are currently two principal stages in the UK planning process at which members of the public can become involved: at the stage of plan creation, with the planning authority considering many different interests before drawing up a plan, or in the form of an opportunity to object to a specific plan or development, where the planning authority must defend its position (Cullingworth & Nadin, 2002, p. 360) [cited in Appleton et al, 2005].

Under the Planning and Compulsory Purchase Act 2004, all UK councils, are "required to prepare a Local Development Plan (LDP)". "As a part of the LDP process, the Council intend to engage with residents, service users, stakeholders and partners in a meaningful and cost effective way. The Assembly Government's stated intention in changing the planning system is to make it faster, more responsive to change and to improve community involvement" [Davies, 2006]. According to Davies [2006], "the council is committed to involving as many people as possible...within the planning process regardless of age, colour, ethnicity, sex, age, marital status, sexual orientation, disability, religion, language or nationality" [Davies, 2006].

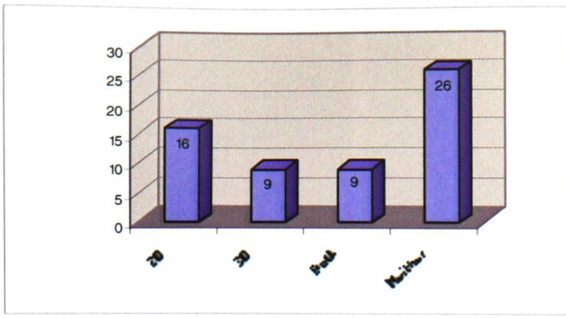
According to Cullingworth [cited in Appleton et al, 2005], the main function of the Planning Process is to "ensure that the wide variety of interests at stake is considered and that outcomes are in the general public's interest". The Rhondda Cynon Taff 'Delivery Agreement' stated that "The Council is committed to working in partnership with the community as a whole throughout the plan making process" and will involve a wide range of interested parties. According to Oh et al [2005], from the National Institute of Information and Communications Technology, "The planning stage of a project is very important in determining the fundamental view of the whole project...It is at this stage at which decisions are made regarding the course of the plan of the entire project", it should therefore be equally important for members of the general public who are effected by new developments, or live close to new developments, to participate in this early stage. It is currently more commonplace for members of the public to be asked their opinions once a design has been drawn up, at which point their views may be too late and may not even be considered. Opportunity should therefore be given, for members of the public to become involved in the planning process from the outset, giving their opinions during this stage may aid designers in creating a more sustainable development.

Stage 1: Is 3D technology utilized within the building design profession?

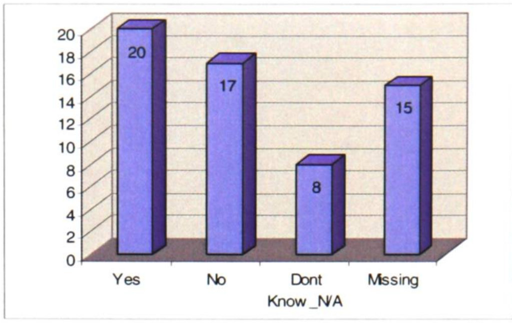
The first stage of this research investigated whether the Building Design Professionals are currently creating 3D urban models in order to display developments to their clients or the public. This stage was important to the research as it gave an insight into the current trends adopted within the BDP and their potential to offer 3D models to the public.

In order to obtain information regarding which 2D or 3D CAD software packages are being utilised within the Building Design profession (BDP), a questionnaire was designed which included topics that would help build an understanding of what, and how the chosen software is being used. The survey was conducted in September 2003, and targeted BDPs, which included Architects, Interior Designers, Surveyors, Engineers, CAD Technicians and Property Developers. A total of 400 companies were sent a questionnaire and 60 responses were achieved, giving a 15% response rate.

Results from the questionnaire showed, in regards to the use of computer aided design, that 42% of the respondents are currently utilising computer technology within the building design profession. The percentage of those using 2D CAD were 26% (16), those using 3D CAD was as little as 15% (9), and only 15% (9) of respondents used both.



Graph 1:The use of 2 or 3D



Graph 2: Industries willing to use 3D

The majority of respondents, who currently use 3D software were the Interior Design group, who also proved to be the youngest of the 6 groups. The most commonly used software and add-on packages, were AutoCAD and Photoshop.

Similar surveys have been conducted by other researcher, the results of which reflect those found in Survey 1 [Arif et al, 2001, Smith, 2000, Green 2004, Green 2005]. Results from other researchers in this field has shown that AutoCAD is the most common software package, not only in the UK, but also in South Africa, Canada, Scandinavia, Denmark, Finland and Sweden.

Robert Green, Manager of Cadalyst magazine conducts an annual survey to keep abreast of market trends in regards to 2D and 3D software. His research has shown that between 2003 and 2006, AutoCAD has been the most dominant software, regardless of new developments in the field of 3D technology. Green [2004] concluded by stating that "a lot of people out there are running their businesses on AutoCAD" even 25 years after it was first released. It seems that "no matter the reason, 2D still rules and totally 3D design-enabled businesses are in the distinct minority" [Green, 2004].

The survey showed that the highest percentage of building design professions only produced 2D plans and Elevations. The reasons given for not adopting 3D technology to produce models were the cost of 3D software packages, the time of training and the cost of training and the amount of time it takes to generate one model. This is problematic because, from the perspective of this research, it is the authors belief that 3D technology is essential if the general public are to be given a say in proposed developments in their area.

Stage 2: Is 3D technology attainable within the building design profession?

In order to investigate whether current softwares are capable of urban modelling a subjective trial was conducted. In the trial, the use and outcomes from such packages as AutoCAD, ArchiCAD, Revit, 3D Studio Max, 3DFloorPlan and TurboCAD were evaluated. 3D FloorPlan and TurboCAD were basic modelling packages which could be bought on the high street for as little as £20. To overcome the cost of training, no training was provided and all software packages were learnt through the use of 'help' menus and tuition provided with each software package. To overcome the problem of time, a two week slot was given to learn each package.

The trial involved each software being used to create an image of an exact building, which would therefore allow for easy analysis. The result of this trial can be seen below:

Figure 1: AutoCAD

Figure 2: ArchiCAD

Figure 3: Revit

Figure 4: 3DFloorPlan

Figure 5: 3D FloorPlan and 3DS Max

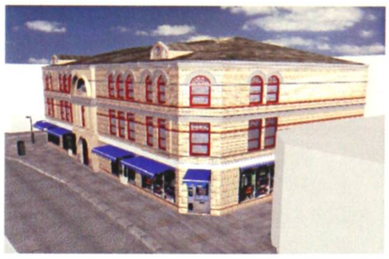


Figure 6: AutoCAD and 3DS Max

3D Floor Plan could not give the desired results and TurboCAD was dropped from the trial due to software restrictions. Revit was the most favoured software but AutoCAD proved to be a very strong competitor even in regards to 3D. The trial showed that the 26% of respondents from Survey 1 who currently use AutoCAD for 2D outputs could advance to 3D without the expense of new software and without the need for expensive, time intensive training.

In order to place the building within its environment a survey was carried out to measure the level of the terrain at different points. In the case of the building shown above, only a small area was surveyed, however as part of this research a larger model was required, and surveying such a large area would take days to complete. As a result an experiment was conducted to investigate whether, Lidar Data, could be used within the CAD packages.

Lidar Data (Light Detecting and Ranging) is the process of attaching a Laser, INS (Inertial Navigation System) and GPS Global Positioning System to an aircraft which omits laser beams whilst flying over the required area. The time it takes for the laser to hit the ground and return to the aircraft is recorded. Using speed of light calculations the height of the ground or object can be calculated. Millions of data points can be recorded during one flight.

The use of Lidar Data within the CAD model would therefore reduce the time required, not only for collecting the data but also inputting the data into the computer in order to generate a 3D terrain model.

Stage 3: Is 3D technology a feasible option within the building design profession?

Survey 1 showed that one of the reasons the Building Design Professionals do not currently use 3D technology is the time required to generate one model especially if needing to place the model in its own environment. Combining CAD software packages and GIS software packages may help to reduce the time needed to generate an Urban model by gathering the data, which include changes in the lay of the land, building heights and building perimeters.

This data can then be triangulated show a 3D model, as shown in figure 8 below. The process of triangulating the data takes only minutes, where carrying out a land survey of the same area would take several hours.

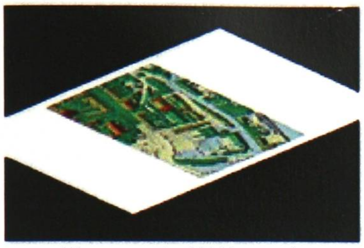


Figure 7: No 3D Properties

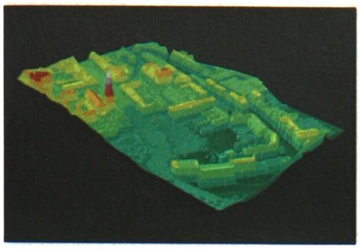


Figure 8: ArchScene and 3DStudioMax

Figure 9: St Catherine's Church, Pontypridd

In order to combine data from CAD and GIS sources, it was firstly necessary to examine the file formats and data transfers between standard commercial available software packages. The CAD software provided for this investigation included AutoCAD, ArchiCAD, Revit, TurboCAD, 3DFloor Plan, 3D Studio Max and G Max. The GIS software used was ArcGIS 9 and ERDAS Imagine 8.7. To commence the experimentation a list of the available file formats within each software package, in order to pin point any similarities between the software's. This can be seen in Table 2 below.

AutoCAD	ArchiCAD	Revit	TurboCAD	3DFloorPlan	3D Studio Max	G Max		ArcGIS Inc ArcMap ArcCat ArcScene	ERDAS
3DS	BMP	BMP	3DS	BMF	MAX	GMAX		ArcMAP Doc	aol
BMP	DGN	DWG'04	DGN	DXF	3DS	P3D		ArcMAP temp	C.img
DWG	DWG	DWG'00	DWG	VRML	AI			ArcSCENE Doc	ALL Raster Ext
DWS	EMF	DGN	DXF		ASE (ASCII)			AI	OVR
DWT	GDL	DXF'04	TCT		ATR			BMP	Arc Cat
DXF	GIFF	DXF'00	TCW		BLK			DBF	BIL
DXX	MDE	JPEG	TCW 6.5		CHR			DXF	BIP
EPS	PMK	Microstation DGN			DF			DWG	BSQ
JGS	PNG	RVT			DWG			EPS	GDB
JPEG	TIFF	RFA			DXF			EMF	BMP
PCX	MWMF	RTE			FBX			GIFF	DT1
PNG		SAT			IGE, IGS			JPEG	HDR
RLC					LAY			LYR	N1
TGA					LP			PMF	EOS HDF
TIFF					LS			PDF	ERS
SAT					SHP			PNG	GIS
STL					STL			SHP	IAN
WMF					VW			SVG	1A
					WRL, WRZ (VRML)			TIFF	FIT
									GIF
									GLT
									GRRID
									STK
									MDL
									GMD

Table 2: Available File Formats

Although Table 2 above shows that there are common file formats shareable between the software packages, further investigation showed that not all file formats resulted in a 3D model, and instead the shared results showed a 2D outcome, which could not be used within a 3D computer generated model.

The investigation which tested the compatibility of the software listed in Table 1 above was carried out in 2003 and re-tested in 2005. The investigation comprised of a simple 3D model of a house, being built within each CAD software and saved in the file formats highlighted in Table 1. Once saved the model was opened in the GIS software.

The results showed that, although there are several compatible file formats, when the model was opened in GIS, it did not contain 3D data, and the model could only be seen as a 2D image, which is shown in Figure 10 and 11. Figure 12 shows the results of opening the model in ArcCatalogue, having been saved as a DWG and DXF file in TurboCAD, although the model is opened in 3D all the coordinates were lost, which resulted in the roof repositioning at ground level.

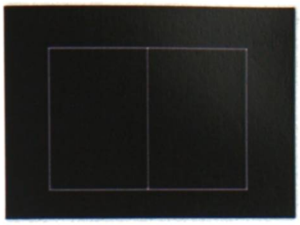


Figure 10: Bitmap opened into ArcScene

Figure 11: Dwg file opened within ArcCatalogue

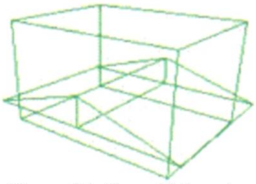


Figure12: Dwg, Dxf and DNG file in ArcCatalogue

3D Floor Plan and 3D Studio Max were the only two packages from the software tested, that resulted in a 3D model being displayed as shown in figures 13 and 14. 3D FloorPlan was an add-on package supplied with TurboCAD, which was purchased from 'Games Group Ltd' for £19.99.

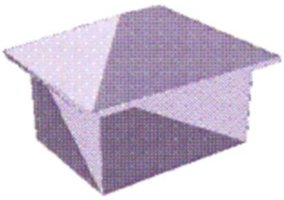


Figure 13: DXF 3D Polygone opened into ArcScene

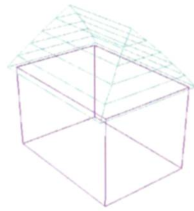


Figure 14: 3D DXF and DWG within ArcScene

Once this test was conducted, it was reversed. The first half of the test looked at whether CAD data could be opened and used within GIS. The second half tested whether a GIS model could be opened within the CAD software.

In order to carry out this investigation a small section of terrain was selected and saved/exported from the GIS software. Once saved and exported using the highlighted file formats listed in Table 2, a test was conducted to see whether it could be opened/Imported into the CAD software.

Once again the results of this investigation showed that it was possible to open some GIS files within a CAD package but, as shown in figure 15 and 16 below, only as a 2D image.

Figure 15: AutoCAD/image

Figure 16: No 3D properties

However, similar to the first half of this investigation, it showed that once again 3D Studio Max was compatible with the GIS data and as a result a 3D terrain model was opened from a VRML file format saved within ArcScene.

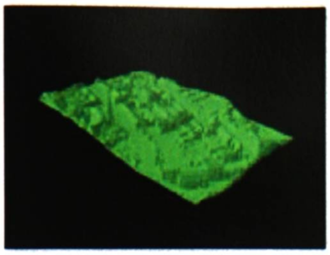


Figure 17: ArcScene and 3D Studio Max

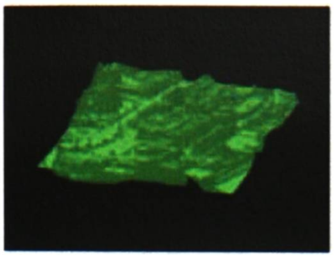


Figure 18: ArcScene 3D Studio Max

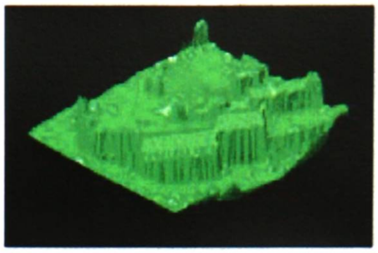


Figure 19: ArcScene and AutoCAD

Now that there is a possibility of opening the GIS data within 3D Studio Max it is possible to export the model as a dwg or dxf file, which could then be opened in AutoCAD and other CAD software. The data contains large amounts of noise, therefore as stated by Tao [2004] the "overall modelling problem is then one of fusing multi-source data consistently and accurately"; this can be overcome with some time and effort.

When the Lidar data was collected it needed to be triangulated so that a solid surface could be produced. The images below show the lack of detail presented in the Lidar data. Figure 20 shows the extent of the area, where Figure 21 has focused closely on one specific area and displays the noise present in the data. The large spear shape to the left of the second image represents a church steeple.

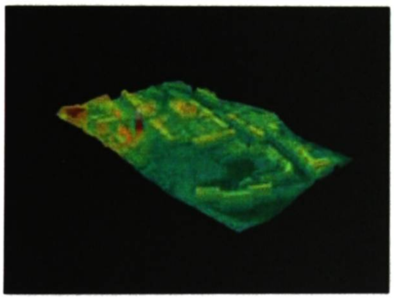


Figure 20: The Urban Area of Pontypridd

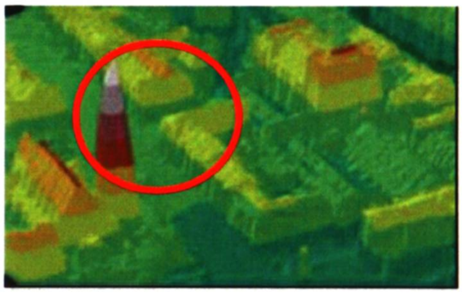


Figure 21: St Catherines Church, Pontypridd

On close analysis, the Lidar Data contains such a large amount of noise that it could not be used within the model and was only used to collect height data. Figure 20 above shows the extent of the area, Figure 21 has focused closely on one specific area and displays the noise present in the data. The large spear shape to the left of the second image represents the steeple of St Catherine's Church, Pontypridd. (St Catherines Church was chosen to demonstrate the process of generating an urban model with the use of Lidar data. It is also proximate to the proposed development used in the main Survey ~ see below).

The Lidar data proved to be a quicker, yet inaccurate method of gathering building heights and parameters. It is advised that before an accurate model can be created that measurements are taken on site, and that overhang measurements are collected due to the data being generated from above.

Due to the lack of detail displayed by the Lidar Data, the triangulated data was imported into a modelling package which allowed buildings to be removed, currently unidentifiable due to the unevenness of the triangulated surfaces (Fig 22) and replace them with more geometric representations (Fig 23) and (Fig 24).


Figure 22: Plan


Figure 23: Plan with geometry


Figure 24: Perspective view

If each building was surveyed and modelled individually it would result in a very accurate and detailed model, however, this method is extremely time consuming and highly dependant on human input. Another method of accurately modelling an urban scene is with the use of digital imagery that can be mapped to the geometrical shape to accurately represent the existing building. The use of the modelling software made it possible to not only replace areas of the Lidar data, but to replace it with solid geometrical shapes more appropriate to represent the existing building. In order to add realism, the chosen software also allowed for buildings to modelled and different textures from digital imagery to be added.
For proposed developments this method of generation would not be an option due to the buildings not currently existing.

The biggest advantage of producing an urban model is that "it takes reality as the base of modelling." [Sequeira et all, 2002]. When modelling an existing environment it is less time consuming to use the acquired digital images and map them to the appropriate area in the modelled scene. This will also enhance the realism of the overall model.

The terrain data shown in Figure 20 and 21 previously, has uneven surfaces and in some levels are incorrect and important information such as walls or fences are missing. "Continued improvements in computer performance, software integration, and the availability of high resolution digital mapping and imagery have combined in recent years to greatly enhance the ability to generate 3D virtual environments" [Lovett, 2005]. Schneiderman [2003] suggests that to make a 3D image look good is to "avoid unnecessary visual clutter, distractions, contrast-shifts, and reflections." However, removing these elements may reduce the overall realism of a computer generated model.

Figure 25 shows how the Lidar data displayed the building and surrounding area. Figure 26 illustrates how the Lidar data was used to give a 3D footprint of the building, and was deleted using the software's editing tools once the new building was placed, as shown in figure 27. Once the new shape was in place materials were mapped to

add realism (figure 28). Figure 29 shows the completed St Catherine's Church model. The church is a significant area for this research, as plans for a high profile development have been excepted for a multi storey car park to be build adjacent to the church which caused much opposition.

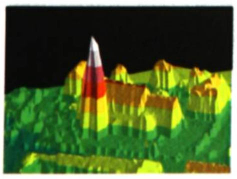


Figure: 25

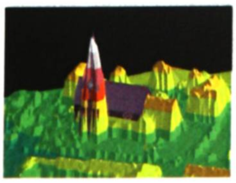


Figure: 26

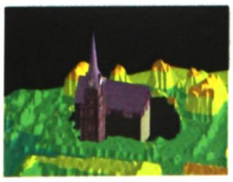


Figure: 27

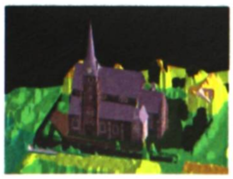


Figure: 28


Figure: 29

Although the Lidar data could not be used in the finished model, as shown in the Figure above, its use helped to reduce the time by eliminating the need for a land survey. Interoperability between CAD and GIS software would allow buildings created in CAD packages to be placed within a terrain model created in GIS packages. This would allow for a much truer representation of an urban environment to be created quickly and efficiently.
Using the process discussed above, it was possible to generate a realistic urban model of Pontypridd from the Lidar data illustrated in Figures 20 to 24. The modelling process can be seen in the images below.

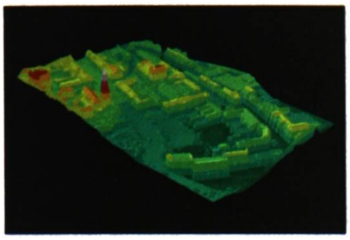


Figure 30

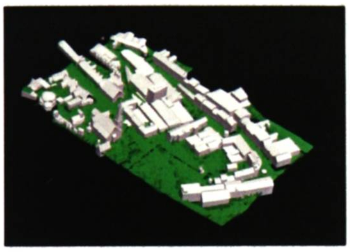


Figure 31

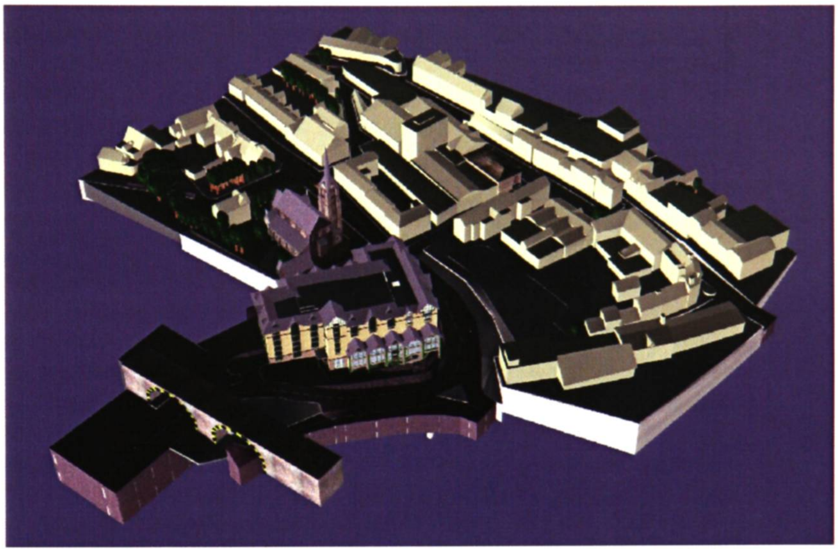


Figure 32

Figure 32

Figure 30 illustrates the extent of the area captured by the Lidar Data. In Figure 31, all of the Lidar buildings have been replaced with a geometric model used to represent the buildings perimeter. In Figure 32 all of the Lidar Data has been replaced. Figure 33 Shows the Proposed development adjacent to St Catherine's Church.

Stage 4: Does the public want/ need 3D technology?

Currently the methods for involving members of the general public in the planning process are limited. The use of 2D plans, sections and elevations as a form of presentation, can sometimes cause confusion. According to Appleton [2005] "the public do struggle to turn 2D maps and plans into 3D mental images. Specific issues include problems orientating themselves, and trouble imagining the wider picture" [Appleton et al, 2005]. Unfortunately 2D plans and elevations are the norm.

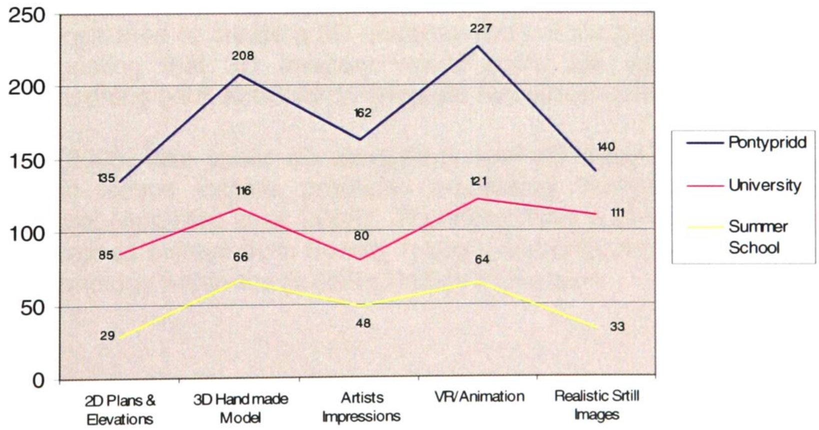
From the outset of this research the purpose has been to prove that public participation will be increased if virtual reality/ animations are provided to showcase proposed developments. In order to achieve this, an experiment was held. An exhibition was setup so that members of the public could look at different presentations of a live development proposal. When entering the exhibition room the participant were confronted by a professionally crafted hand made model, there were professional architectural drawings, an experienced artists impression, and several high quality still images were also displayed.

The virtual reality/animation was placed in a far corner of the exhibition room, displayed on a small screen and was limited to a single walk-by. So this exhibition was set up to try and disprove the contention that 3D would be preferred by the public.

In order to understand what the Public need in regards to understanding proposed developments, an exhibition was held which displayed several different techniques which could be used to present proposed developments to the general public. These techniques included 2D plans and Elevations, a 3D Hand made model, Artists impressions, Realistic still images and a VR/Animation displayed on a computer screen. Each displayed technique illustrated the development at St Catherine's Corner. During the exhibition participants were asked to fill out a questionnaire which aimed to determine which technique was most favoured by the public. The exhibition was held at 3 locations, each targeting a different group of individuals. The first was held at Pontypridd Museum and targeted the non-professional sector, 66 responses were gathered during this exhibition. The second was held at the University of Glamorgan and targeted the professional sector, 34 responses were gathered; the third was held during summer school at the same University and targeted the younger generation, 16 responses were gathered.

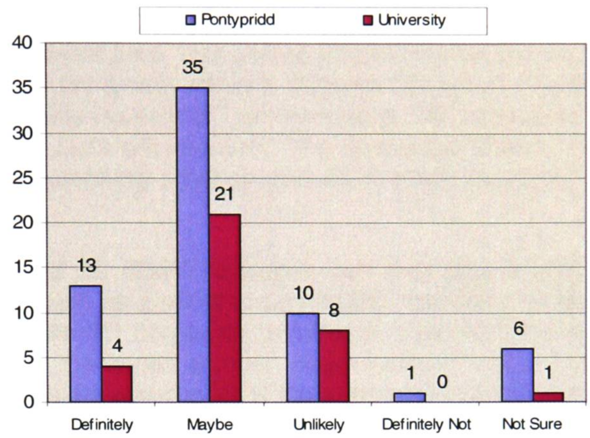
There was a total of 116 responses given from the participants of the three exhibition/surveys. The results showed that Virtual Reality/Animation was the most favoured technique throughout. The percentage of those who favoured this technique was 42% (49). The second most favoured technique by the participants was a Hand-Made 3D model with an overall percentage of 33% (39). Clearly people prefer 3D representations. The technique chosen as the third most favoured technique was also the Hand-Made model with 22% (26) and the Realistic Still Images with 21% (25). The technique placed in forth position were the Artists Impressions with 25% (30) and the least favoured technique throughout the three surveys were the 2D Plans and Elevations with an overall percentage of 39% (46) ~ the technique actually used in the majority of developments.

Graph 3 below illustrates a weighted analysis of the preferred software from each group. Every technique chosen as the most favoured form of presentation was given 5, 4 points were given to the second choice, 3 for third, 2 for fourth and the least favoured technique was given 1 point. The graph shows that there was a similarity between all three groups and target market.



Graph 3: Weighted Analysis

When the respondents were asked if they would participate more in planning evens if their most favoured technique was used as a method of presentation, the results showed that, 56% would consider attending events, 17% would definitely attend, and 18% admitted that it would be unlikely that they would attend. This question applies to the first two groups only. The third group of school children were not included in this question.



Graph 4: Attendance increase if 3D technology was used

The results of this survey has shown that, regardless of age and education, 3D technology is the most favoured technique. With the adoption of 3D technology there may be a 56% rise in public participation. Even if the more modest 17%, who state that they would definitely attend; actual became involved, a massive transformation of the participation process would occur. In a 3D computer generated model "all three dimensions are continuously available and represented analogically as actual distances on the display" [Smallman et all 2001].

The benefit of 3D imagery, especially in architecture and urban re-generation is that it creates one view that does not have to be supported by several 2D views, by this I mean that in many cases such as Architecture, clients are given a plan view and 2 to 4 elevational views which must then be mentally positioned to create a 3D understanding of the building. Smallman et al [2001] agrees, suggesting that 3D imagery would spare the viewer the "mentally demanding process of scanning back and forth to integrate two planer views."

According to Appleton [2005] "the public do struggle to turn 2D maps and plans into 3D mental images. Specific issues include problems orientating themselves, and trouble imagining the wider picture" [Appleton et al, 2005]. Therefore there is an overwhelming need for 3D technology, however as evident from Survey 1; this is currently not a possibility due to the lack of use of 3D technology within the Building Design Profession.

Conclusion

This research has shown that 3D CAD can now play a vital role within the Planning process in regards to public participation. Stage 1 showed that 3D technology is not much embraced within the Building Design Profession in Wales, however as shown in Stage 2, the software is available within 28% of the design industries currently using AutoCAD for 2D outputs. Stage 3 showed that GIS data can be used within CAD packages, however, the quality of the data was not appropriate, at the present time, and unless improvements are made to the quality of the data it remains unsuitable for a use within a detailed 3D urban model . As technology develops the process of creating realistic 3D environments will undoubtedly get quicker and easier, and the quality of Lidar Data will improve. The final stage showed that there is a need for 3D technology within the planning process and as a result more companies should be adopting this technology.

Developments in 3D CAD and 3D BIMV packages can now play a vital role in conveying understanding to the viewer, such as a client or committee member. As technology develops the process of creating realistic 3D computer generated reproductions of real life scenery, although still time consuming, becomes a much more realistic task. The biggest problem faced by computer modellers is the complexity of the surrounding environment.
The ability to present proposed developments is an important aspect of urban regeneration schemes, as the height of understanding from clientele and members of the general public is important in regards to the acceptance, or alternatively the rejection of the proposed scheme. In order to generate a more realistic model in terms of the urban terrain this the Interoperability between CAD and GIS software was examined.

The results of this test showed that in 2003 and 2005, when this test was carried out, there was compatibility between the two software types, through the use of 3D Studio Max, a Modelling and Rendering package. This therefore makes it possible to use terrain data created for Lidar Data, and use it with a CAD package, where a proposed urban scene could be created.

To illustrate the 3D outcomes of several different 3D CAD packages, a trial was conducted. The trial showed that overall, the final result of all the software was very high. AutoCAD although considered a 2D draughty package by most users, has a very high quality output, yet is very time consuming. The tuitions are not very helpful and therefore training or a lot of patients is needed to learn.

It had been hoped that a lesser priced software would be adequate so to allow more building design professionals to progress into 3D, however this proved not to be the case. "The availability of cheaper and more user friendly computers and software implies that even small and medium-sized design offices will start using CAAD" [Verbeke et al, 2002]. The results of this trial showed that Revit was the strongest competitor in regards to ease of use, and outcomes, the two lower end software packages unfortunately proved to be unsuitable for creating a realistic model.

"Technology is developing all the time, and the influence of new media and computing technologies has certainly improved the ability to generate realistic visual representations. According to Bulmer [2001] and agreed by the authors, 'Urban simulations; that is computer generated simulations of the built environment, are an effective means of improving the public's participation in the planning process'.

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