Virtual Reality Urban Modelling - An Overview

Emine Mine Thompson
School of the Built Environment
Northumbria University
Newcastle upon Tyne, UK
Emine.Thompson@unn.ac.uk

Margaret Horne
School of the Built Environment
Northumbria University
Newcastle upon Tyne, UK
M.Horne@unn.ac.uk

David Fleming
School of the Built Environment
Northumbria University
Newcastle upon Tyne, UK
David.Fleming@unn.ac.uk

Abstract

This paper offers an overview of the increasing use of Virtual Reality (VR) technologies for the simulation of urban environments. It provides a summary of cities worldwide where three-dimensional computer modelling is being utilised to aid urban planning. The study considers the need for a digital representation of cities and raises issues pertaining to advantages, barriers and ownership. A case study of a pilot project on the visualisation of Newcastle upon Tyne is examined to show an approach adopted for the representation of this city in North East England. The process of this visualisation is summarised and future research is outlined in relation to this city model.

Keywords

Virtual Reality, 3D Modelling, Visualisation, Ownership, City Models, Town Planning, Newcastle upon Tyne England.

1. INTRODUCTION

The modelling of an urban environment, from aerial view maps of medieval times to more accurate city plan projections of Renaissance to inexpensively produced-standardised, printed 2D maps of 19th Century is not a new concept. Over the centuries these 2D plans and representations and maps made for different purpose have helped develop our cities. Over the last 40 years, the introduction of Computer Aided Design (CAD) and other software packages which make 3D modelling achievable is shaping the way we create and use city models. Similar to their real life equivalences city models are never a finished product. Cities with ever changing and developing urban formations, trends and citizens' needs, require a dynamic platform where these modifications are possible with ease. The advances of information and communication technology, powerful hardware and software availability and accessible 3D data are making it possible to create these platforms. This paper offers an overview of the role of Virtual Reality (VR) in urban modelling and considers the issues in adoption of VR for the representation of cities. This paper also describes our work on developing a virtual Newcastle city model.

2. A GALLERY OF CITY MODELS

"The information that exists about a metropolis is hard to comprehend in its totality [therefore] good representations allow rapid understanding of the relevant features of a data-set" (Whyte, J., 2002). VR urban models can be simply described as computerized graphical representations or visualisations of any city and its components. The final product should be accurate and objective to the rate and objective to the cause, we call this *Forensic Modelling*.

"The importance of 3D reconstruction of buildings, cities and urban landscapes is becoming more recognized and acknowledged" (Horne M, 2004). Urban planners are making use of computer technology for many reasons, and research areas have been classified to include transportation modelling, agent-based modelling, GIS and public participation, planning and decision support, urban morphology, spatial analysis and virtual cities. Several of these fields overlap as advancing tools and technologies are developed to aid the management of urban environments. Advances in real-time virtual reality are demonstrating great potential to contribute to the design and planning of cities and an increasing number of cities are adopting this technology to aid the decision making process. Much research has been conducted on 3D city models. The Corporation of London commissioned CASA[1] to carry out a research of 3D models of cities and this study produced more than 60 3D city models. According to their research these models ranged from CAD models through various 3D GIS to VRML Web content and related simulations. At the end they selected eight (Tokyo, New York City, Berlin, Glasgow, Helsinki, Philadelphia, Washington D.C., Jerusalem) cities for more detailed investigation. One of the most compre-

[1] CASA (Center for Advanced Spatial Analysis) at UCL London: http://www.casa.ucl.ac.uk/3dcities also see http://www.casa.ucl.ac.uk/3dcities/table_all.htm for a more comprehensive list.

hensive reviews done by Batty et al. in 2000 was a result of the above research. They listed more than 35 cities with greater than one million population. Table 1 shows an enhanced list of city models. The efficient production and utilization of the 3D city models is enhancing urban planning. However "it is still necessary to think about the amount of detail that is necessary for different applications, different phases and different target groups to be used in a 3D representation of the spatial plans" (Pleizier I, et al, 2004).

Table 1: Some of the visualisation projects[2] of cities (in some cases part of a city) around the world

North, South and Central America	
Mexico City, Mexico	Detroit, USA
Santiago, Chile	Houston, USA
Toronto, Canada	Los Angeles, USA
Vancouver, Canada	New York, USA
Atlanta, USA	Philadelphia, USA
Baltimore, USA	Portland, USA
Boston, USA	San Diego, USA
Chicago, USA	San Francisco, USA
Cleveland, USA	Seattle, USA
Denver, USA	Washington DC, USA
Europe	
Hard, Austria	Nicosia, Cyprus
Salzburg, Austria	Bratislava, Slovakia
Vienna, Austria	Bath UK
Florence, Italy	Bristol, UK
Parma, Italy	Glasgow, UK
Berlin, Germany	Harrow, UK
Frankfurt, Germany	Hounslow, UK
Giessen, Germany	Leeds, UK
Hoechst, Germany	Liverpool, UK
Karlsruhe, Germany	London, UK
Munich, Germany	Nottingham, UK
Reutlingen, Germany	Sheffield, UK
Saint Petersburg	Slough, UK
Warsaw, Poland	Southend-on-Sea, UK
Lisbon, Portugal	Swindon, UK
Berne, Switzerland	Workington, UK
Paris, France	York, UK
Izmir, Turkey	
Asia, Middle East and Africa	
Delhi, India	Yokohama, Japan
Hong Kong	Beirut, Lebanon
Singapore	Dubai, U A Emirates
Tokyo, Japan	
Australia	
Sydney, Australia	
Adelaide, Australia	

[2] 3D models, photogrammetric models, VR models etc.-the information gathered from Batty M., et al (2000a), Dikaiakou M. et al (2003), Dokonal W.,et al, (2001), Ftácnik, M (2004), Hadjri K., (2004), Horne M., (2004), Peng C., et al (2002), Piersch S., (2001) and z-mapping and 3D Web Technologies web sites.

3. CHANGE IN THE VISUALISATION OF CITIES

Wooden or cardboard 3D urban models are still being used by many local authorities all over the world as representation tools to show changes in the urban fabric. However, a physical scale model, because it is expensive and difficult to alter, is not a flexible tool to display the effects of a new developments. The only way to see and "experience" the city in these models is via the "bird's eye view" and therefore judging implications of a new development at a human scale is almost impossible. These physical models required 2D plans, perspective drawings, photomontages etc to give an understanding of the complex urban structure. Despite these difficulties, wooden models are still being used and as Day A. (1994) explained in the example of the City of Bath wooden city model, they have been used for "considering changes at an urban scale".

"Computers [2D and 3D computer aided drafting] have been used in architecture and urban planning research" (Mitchell, 1996) and practice for more than four decades now. Although the computer as a tool is a great help for creating accurate drawings for the proposed scheme, it is sometimes not easy to put these schemes into the urban context without the factual representation of the surrounding. "Urban planning is a complex process encompassing aspects of social, economic, physical and spatial significance" (Bourdakis, 1997). During this complex process of planning applications, approvals, community involvement etc, having a flexible tool to interact with different parties/stakeholders and especially with the model is very important (Figure 1).

This interaction and "the quality of visualisation leads to better insights and better understanding of the spatial plans" (Pleizier I, et al, 2004) and more accurate and satisfying results for all parties involved.

Day et al (1998) point out that "the computer simulation of cities has emerged from several traditions:

1. City databases

2. City maps
3. City models
4. City visualisations
5. Representation of City behaviour"

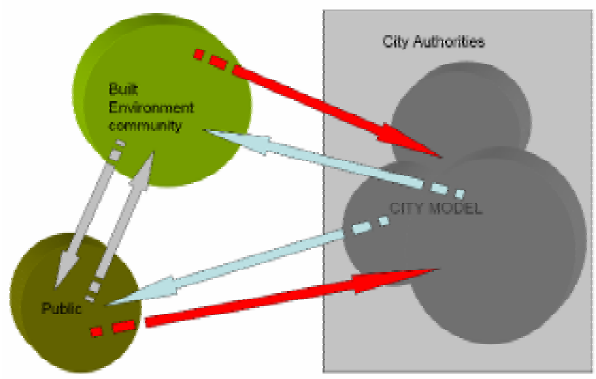

Figure 1: The current complex relationship between the parties/stakeholders for a proposed development

Data exchanges and analysing and observing the city model is vital for urban planning. This could be done with today's technology at ease. This technology can offer the highest level of visualisation-an immersive and interactive VR environment where involved parties can navigate through (walking, flying, etc.) the city model on different platforms ranging from PC screens to semi-immersive large screens to fully immersive CAVE environments etc.

3.1 Utilizing VR City Models

VR city models are been used to facilitate the dialogue with the local authority and the other stakeholders involved for a specific scheme and allow general debate on the city's future developments. They also offer an opportunity to recognize and understand the technical and visual aesthetic data easily. Bourdakis (1997) suggests that "VR urban models can be used at two levels of complexity/engagement; low level, as a *presentation* and *evaluation tool* as well as a *planning support - analytical tool*, more advanced, real-time editing tool to be used by specially trained professionals" and emphasises that "Urban models should be used to organise such information [city related information-from visitor specific aids to engineering focused information] and work as 3D fully interactive maps/indices of our cities/lives".

The 3D city can be created for a very wide range of purposes. Batty M et al (2000) define these different applications into 12 different categories of use:

1. "Emergency Services
2. Urban Planning
3. Telecommunications
4. Architecture
5. Facilities and utilities management
6. Marketing and economic development
7. Property analysis
8. Tourism and entertainment
9. E-commerce
10. Environment
11. Education and learning
12. City portals"

These 12 categories have been enhanced and grouped into four categories by Shiode N., in 2001 as:

1. "planning and design,
2. infrastructure and facility services,
3. commercial sector and marketing,
4. promotion and learning of information on cities"

From these two classifications on use of city models, following table (Table 2.) is created. This table illustrates the interest shown by the different stakeholders towards the city models.

3.2 Construction of the VR City Models

Cities are complex physical and social entities. "The nature of urban environment that comprises a number of elements from landscape modelling to transportation networks to various socio-economic exchanges. Every city possesses a unique structure with its own momentum" (Shiode N., 2001). This unique structure needs to be transferred into the digital environment realistically. In order to use VR city models in continual process of consultation, decision making and revisions they should be based on accurate, detailed and spatially unambiguous data. According to Discoe (2005) the "basic steps in creating three-dimensional visualisation of landscape [and in general any digital model] are to acquire raw geographical data, process them into an appropriate form, then use them as inputs to software which will construct the three-dimensional geometry" Therefore it can be said that data sources and choice of software and hardware plays a major part in constructing a VR city model.

Following is a summary of digitising/visualisation process:

- Data sources
  - Data capturing steps: aerial photography, 2D data, street level photography and laser scanning, auxiliary data, texture mapping, data processing etc.
- Software
- Accuracy level
  - Levels of abstraction / levels of detail

Table 2: Stakeholder's Interests in Urban Models

CITY AUTHORITIES	
Planning and Design Related Activities	Urban planning scenarios Planning and decision support Spatial analysis What if scenarios GIS applications Development control Planning permission applications Contextual modelling Traffic simulations Transportation modelling Public participation Environmental impact assessments Visual impact analysis
Infrastructure and Facility Services	Climate, air quality, fire propagate, public safety studies Emergency planning Facilities and utilities management Property management and analysis
Commercial Sector and Marketing	Marketing and advertising E-commerce
Promotion and Learning of Information on Cities	Tourism and entertainment City portals

BUILT ENVIRONMENT SECTOR	
Base data resource	Architectural Planning Landscape architecture and planning Construction Surveying Real Estate etc. companies
Maintenance and development plans	Gas Electricity Phone Internet/broadband/TV companies
Marketing and advertising	

ACADEMIA	
Teaching and learning activities	Use and creation of city models City segment models for students projects Context analysis, mass analysis Experimenting ideas etc.
Research	
Consultancy	
Archiving	

- City Objects
  - Terrain and sky,
  - Buildings,
  - Landmarks,
  - Vegetation and landscape modelling,
  - Street furniture, streetscape modelling
  - Populating the model with pedestrian and vehicle networks
- Monitoring, review and updating

3.3 Advantages of and Barriers to VR Urban Models

"The theory and practice of implementing virtual reality visualisation for public participation in urban design have recently been reviewed" (Changfen et al, 2005) and advantages of and barriers to such VR applications have been addressed. The needs of various stakeholders are diverse, yet have to be taken into consideration when creating an urban simulation, if it is to be adopted and used appropriately by all interested parties.

Issues that have been identified from previous research have related to the areas of ownership of such virtual cities and the need for an accurate 3D urban model to be managed by an impartial body (Pritchard, 2005).

Advantages of Adopting VR Urban Models

- *Enhanced communication and easy to explore urban context*

Planning applications, regeneration schemes etc. always involve communities and bring together experts and non-experts together to discuss on issues. Understanding the versatile physical and socio-economical structure of a city is not always easy from a blueprint. VR urban models improve the understanding for this complex data both for lay person, and also the expert.

- *Freedom of movement (movement between different scales and levels of details)*

In contrast to the animations and pre-determined fly-through, photomontages etc., VR Urban models provide freedom of movement to its user. This freedom enables users to see and experience the model from their own viewpoint with no external participation. Being able move in and out of the model (bird's eye view to human scale) also enables users to see the model in different scales as well.

- *Different levels of immersiveness*

With the chosen technology these models can be fully immersive in a CAVE environment or can be semi-immersive with one-to-three screen projections. Also, directly related with portability, these models are transferable to PC/laptop for non-immersive usage.

- *Ability to attach qualitative data to the models*

For different purposes (educational, municipal, commercial etc) various qualitative data can be attach to the VR models such as databases of street names, house numbers, school, hospital, universities, public building names etc. This empowers the model to be used by multiple usages for different circumstances and users. This also enable user to have instant access to diverse data.

- *Portability*

Although the VR city models can cover very big areas, parts of them can be transfered to PC or a laptop. This is a great strength. So instead of people coming to the models, models can go to them.

- *Formally and informally sharing data with diverse stakeholders*

Using VR urban models on different platforms like networks, intranets etc. enable quick and accurately updated information sharing. Also because it is portable different parties involved can easily access it and give feedback at the same time.

- *Ability to involve diverse disciplines together under one roof*

VR city models like a real city can bring together various experts from wide range of disciplines to contribute to make a better city (From planners to architects to landscape architects to infrastructure constructions to traffic engineers to health care works to academics to surveyors to real estate marketing etc.).

Barriers to Adopting VR Urban Models

- Technical issues (software, hardware compatibility, recurrent updating etc.)
- Organisational issues (management of shared resources, data copyright and ownership issues etc.)
- Ownership of the models
- Privacy and security
- Seduction of visual images

3.4 Ownership of VR City Models

Ownership of city models is one of the strategic subjects that the authors of this paper are interested in. It is a complex issue involving different stakeholders. According to Whyte (2002), "academic projects have shown the potential of VR models at the urban scale and provide good case study examples, but few models built in aca-

demia are being used to their full potential in the planning process [by the relevant municipalities]. Municipal authorities are [also] beginning to use virtual reality in-house, or are working in collaboration with suppliers to develop and maintain city models". Bringing together these separate models (involving time, money and effort) might solve the some of the issues regarding design, production and management of these models. The following sections explain the ownership concept of some of the virtual city projects around the world. It should be pointed that this was a limited exploration with the intention of establishing a base for a further study on the ownership issue of VR city Models.

3.4.1 Virtual LA

Starting from 1980s "The Urban Simulation Team's primary focus is to build a virtual model of the entire Los Angeles basin which can then be used to interactively fly, drive or walk-through the city. The model is constructed by combining aerial photographs with street level imagery and three-dimensional geometry to create a realistic visual simulation of the dense Los Angeles urban environment, detailed enough for the graffiti on the walls and signs in the windows to be legible" (UST, No date). According to William (Bill) Jepson[3] (2006) "The UCLA Urban Simulation Lab and Bill Jepson own the complete Virtual L.A. model(s). They share non-exclusive ownership with their clients for the areas that they commission. However, that does not include any pre-existing Intellectual Property (IP) such as Urban Simulation Lab's extensive landscape, foliage and texture databases".

3.4.2 The Helsinki city simulator

"The Helsinki City Simulator, which was presented for the first time to the public in January 2000 at the Helsinki City Planning 2000 exhibition, contains a virtual model of the Helsinki City centre and a powerful multi channel display system for real time simulation on large screen. The purpose of the simulator project was to build a realistic vision of the future city centre as it is planned today. For architects and planners a virtual model is a platform to test and improve their design. For city residents and politicians the simulator is an easy and very illustrative way to walk and fly in the future city. It provides a good basis for exchanging opinions on future design" (Suomisto J, 2001). Jarmo Suomisto[4] (2006) also explains their stand regarding the ownership of VR models by explaining that Helsinki virtual models are made by Helsinki City Survey Division and owned by them, they also have the rights to sell it. City Planning Department are also buys the basic 3D-models and then add materials such as textures, lightning, new plans etc. Although individual modellers have no right to the model, the city planning department can use these models in their own work and give them to their planning consultants.

3.4.3 Virtual London

"Virtual London is a project funded by the Greater London Authority and CASA University College of London, has been working on this project for many years now. The model is being produced using GIS, CAD, and a variety of new photorealistic imaging techniques and photogrammetric methods of data capture. The core model is aimed to be distributed via the Internet utilising techniques to optimise large urban data sets for broadband distribution" (CASA, no date). According to Michael Batty[5] the ownership of Virtual London is a very complicated issue. There are several vendors who have contributed money and data or donated software to this big project, including CASA, Greater London Authority, Ordnance Survey, Infoterra, ESRI, London Connects etc. Therefore the ownership becomes very problematic and became an issue recently when Google Earth wanted to buy this model [and we believe that still there isn't a clear answer for this problem] (Batty M., 2006).

3.4.4 Beirut visualisation

In the case of Martyrs' Square and 3D Model of Beirut visualisation the VR model is owned by the private sector real estate company Solidere[6] which was created by Lebanese government decree in 1994 to reconstruct entire Beirut city centre, an area of 1.9 million square metres (Horne M, 2004). This company's role is very diverse and acts as a land developer, real estate developer, property owner, property and services manager and operator. Solidere began developing a three-dimensional computer model in 1995 to be used as an interactive urban design tool which could be used to consider building footprint and massing options, as well as maintaining a record of floor space and proposed land use by parcel, block and sector (Gavin, 1996).

It is believed that ownership of VR Urban models and their management will be a key issue for the future developments.

4. NEWCASTLE UPON TYNE VISUALISATION PROJECT: A PILOT WORK

This project started as an experiment to combine the previously developed Northumbria University City Campus Virtual Model into the city model. With this experiment we wanted to show the close relationship between the city and the campus and approaches to the campus and major landmarks of the city. We found that the resulting product was successful and extendable.

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[3] Director of Urban Simulation Team at UCLA.

[4] Architect, Head of IT in the Helsinki City Planning Department

[5] Director of CASA

[6] Solidere (Société Libanaise pour le Développement et la Reconstruction du Centre-Ville de Beyrouth), is a Lebanese joint-stock company. For more info please visit http://www.solidere.com/solidere.html

4.1 Newcastle upon Tyne

Newcastle upon Tyne is in the North East of England. Today modern Newcastle has a population of 269,500 according to the 2001 census.

The City of Newcastle upon Tyne with its history dating back to Roman times, has been an important settlement. The River Tyne, over the history, became a line of defence, a channel for communication and an artery for trade. Pons Aelius was the earliest known crossing of the River Tyne and the origin of Newcastle as a settlement which provided a regional focus. Since then it has had varied identities from Roman frontier to Norman stronghold to Great Medieval town to home of railways to industrial powerhouse to Georgian planned town[7], which has created a rich and interesting urban texture and culture.

4.2 Urban and Architectural Landmarks

Newcastle upon Tyne with its rich history has several urban and architectural landmarks including The Tyne Bridge, The Millennium Bridge, The Swing Bridge, The High Level Bridge, The Redheugh Bridge, Central Station, The Castle, River Tyne, Northumberland Road, Eldon Gardens, Grainger Town and Grainger Street, Jesmond Dene etc. All of these landmarks are the legacy of Newcastle's rich history. Therefore, from a modelling point of view, such landmarks should be included as a part of a VR urban model.

4.3 Wooden City Model

Newcastle City wooden model has a long history. At this present time this model is located in the Member's Lounge in the Newcastle Civic Centre. It is in 1:500 scale and used as a working model instead of a demonstration model. The first wooden model was created in late 1960s and since then the wooden model has gone through several alterations, and additions. There used to be three model makers working on it. For any major development, the model makers used to create the additions in blue foam (to aid easy amendments etc.) and after the discussions with the architects, and planners these blue foam models were used to make the basis for the wooden additions to the model. Presently there are no permanent model maker workers in the planning department. When there is a need to add or alter things one of the previous model makers comes and updates this new section.

[7] Please visit for more info:
http://www.newcastle.gov.uk/hods.nsf/a/histncl

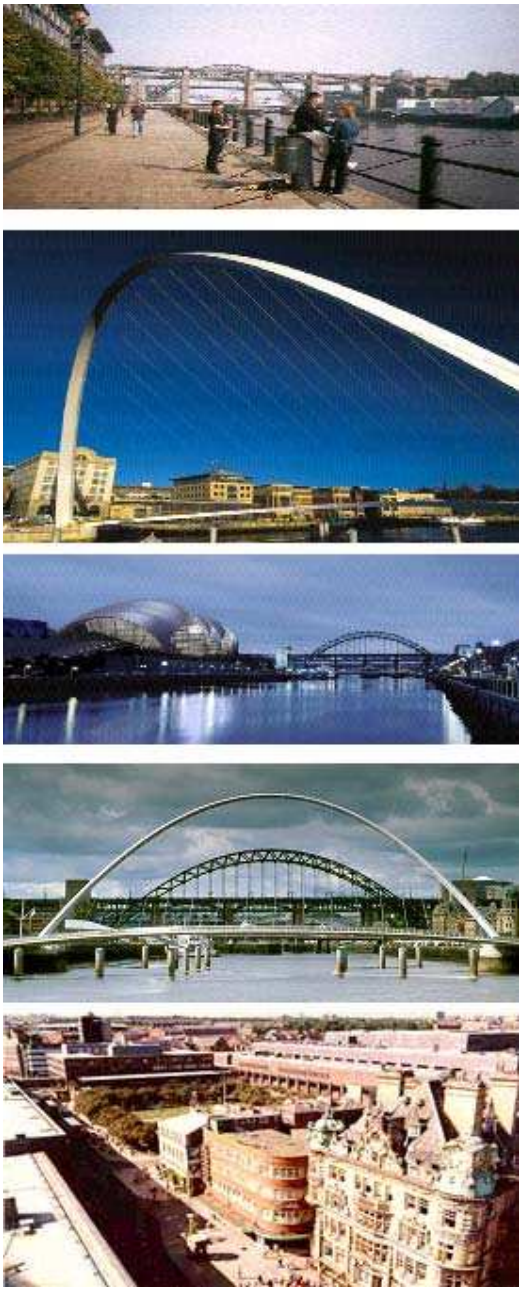

Figure 3: Some views of Newcastle upon Tyne.

Also recently architects who propose new developments generally will have their own model makers and they create a model (generally in cardboard) in the same scale of the city model to show their scheme in relation to city. After a consultation process these models generally are left attach to the city model as an update (Figure 4).

Figure 4: Newcastle upon Tyne wooden model.

4.4 Building a Virtual Newcastle Model

The initial intention of creating the city campus model was to develop and show the close physical links between the city and the campus in a virtual model. The VR model of the Northumbria University City Campus has created great interest both from the faculty and the students and is been used for variety of purposes for teaching and learning and research in the School of the Built Environment (Figure5).

After the completion of this mini-pilot project; the project team[8] saw the opportunities of extending this model into a wider city model. 3D data was gathered from ZMapping[9] and the initial campus model data was stitched to this raw data. The method of getting the campus model into the ZMapping data was a process of isolating the elements that already been created and merging them into the city model. After the alignment of the Zmapping unit scale to the campus scale, the relevant buildings were removed and faces were isolated and detached from the main model.

[8] Project team includes the academics from the School of the Built Environment and modellers from Insite Environments.

[9] For more info Please see http://www.zmapping.com/urban3dmodelling.htm

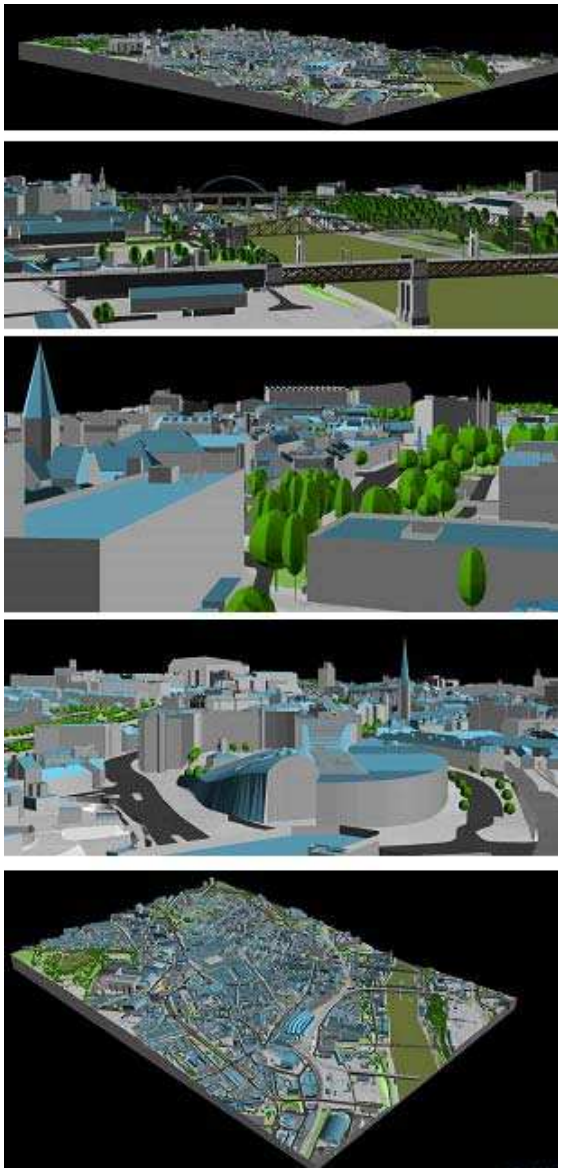

Figure 5: Screen shots from Newcastle VR Model.

Keyboard presses were then created to toggle on and off the Northumbria City Campus in the City Model to show the city model in different levels of detail.

Formal and informal meetings with various stakeholders (architects, planners, landscape architects, etc, and academics from various universities) showed great interest in having a virtual Newcastle. This has led the project team to evaluate the opportunities of having a VR model of the City of Newcastle upon Tyne and approaches have been made to the City Council for further developments.

5. FUTURE WORKS

Apart from extending the city model the focus is now on creating different versions of the model for different purposes and populating it with vehicle and pedestrian simu-

lations. The interest from different stakeholders regarding creating and being able to use this VR Model is increasing. It is believed that this will lead a more functional and flexible city model where various stakeholders can access and utilize the model according to their needs. Further contacts made with the city authorities and it is decided that a definitive model and a development model should be created in order to have an easy access of all the data while expansion of the model in progress Also agreement is reached to setup a "Working Party" to further this development.

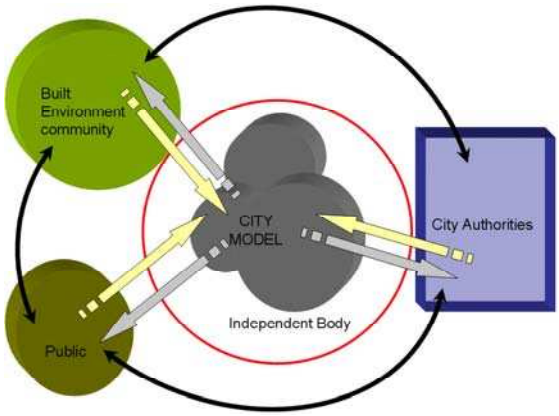

Figure 6. An alternative relationship between the parties/stakeholders involved in the city

Figure 6 shows an alternative process and relationship that can be employed to enhance the understanding and the communication between the different stakeholders in the city. With this approach, Whyte's (2002) observations on lack of utilization of models that had been created by academia, in the planning process, can be rectified if academia undertakes a coordinating role and acts as the impartial, independent body working in collaboration with all the stakeholders to maintain the city model.

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