Imaging Change: The Computer City Model as a Laboratory for Urban Design Research

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The use of an extensive and detailed computer model of the city of Bath, UK, as a laboratory for urban design research is discussed. Bath is a small predominantly Georgian historic city that has been designated a World Heritage Site. Examples are drawn from four kinds of work: the representation of Bath's historic growth (including unbuilt plans), the prediction of the urban design impact of individual development ,proposals, the study and development of explicit and implicit urban design 'rules for the form of existing and new development, and the impact on city form and appearance of policy proposals for urban sustainability.

Key words: urban modelling, planning, public consultation.

1 Introduction

Computer models of buildings, like physical models, are often presented as 'ends': representations which describe a project's form and colour, and perhaps how it fits into a wider environment. The computer model of Bath has always been primarily directed at being a 'means': a means to explore issues in urban design, in the public perception of a city, in the implications on physical form of various strategies for making more sustainable cities, and a means for understanding more about the city's form and history. The model is a laboratory in which prototypes can be built and tested, a board on which urban design games can be played, a storyboard on which the history of the city can be shown, and a virtual world in which strategies can be 'implemented' with no risk to the real world. Primarily the model is about imaging change, about showing in a form that is accessible to a public and political audience how change might look. It allows a pro-active rather than reactive approach to change, a means to influence rather than react to the form of development proposals, and a means to look at 'designing the city' rather than letting the city 'happen' as a result of individual developments. By facilitating the imaging of change on both large and small scales it empowers the public side of the private/public rights debate over who should control urban form. The model of Bath is not alone in having this role -another prime UK example is the computer model of the medieval Old Town in Edinburgh, Scotland [2] - but it is unusual in the degree to which it encompasses the whole of a city centre in considerable detail.

Urban design issues are more obvious and more readily accepted as being critical in a city where the existing built form is recognised as both beautiful and historically significant. Bath, a city accorded World Heritage status, is pre-eminently such a place. It owes its existence to hot springs on the site and was a Roman settlement with extensive Roman Baths (still visible) from the second century AD. In medieval times an abbey was built and became the focus of a small network of narrow streets. In the 18th century Bath became a fashionable place for the wealthy to gather, take the waters, and participate in a social round of engagements. To do this they needed houses, and a series of bold speculative

developments created a dignified setting for their activities. The Georgian building period lasted from 1738 to around 1825, although later Victorian development continued to adopt many of the same urban rules. Bath grew as a series of developments rather than a single development, and there was never any 'grand plan'. Each new stage took cognisance of what was already there and added to it in the light of the architect/ developer's (often the same person's) aims. Each new development also respected and drew upon the architectural language of its context. The city demonstrates what can be achieved when the cohesive form of the whole dominates the individual parts. Bath has World Heritage status because of this totality, because of its streets and places rather than any individual building (Figure

The process of building a large computer model is described elsewhere [3]. It was constructed in the Centre for Advanced Studies in Architecture (CASA) at Bath University using aerial photogrammetry with survey data being entered directly into AutoCAD. The entire model comprises some 200 sub-models, each about an urban block in size, and occupies about 60 MB of disk space in AutoCAD dwg format. Each sub-model exists at three levels of detail to speed up rendering times with the most detailed version containing almost 4 million polygons. As Bath is situated in a valley, a simplified model of the surrounding countryside has also been constructed using a 3D terrain mesh on to which have been pasted bitmap images derived from 1:50,000 ordnance survey maps enhanced m a paint program to appear naturalistic. This puts the urban model in context and means that views from the city centre include the landscaped backdrop that is so important to Bath's setting (Figure 2).

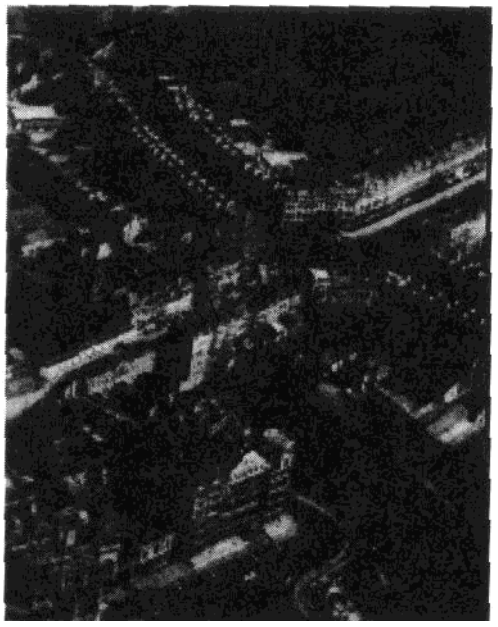

Figure 1

The model is used because it exists: it is an available resource. It generates interest not only in itself but in the kinds of issues that can be explored through computer modelling. It has become a principal resource, a first way in which these kinds of issues can be explored, and its successful use in one urban design arena establishes credibility and motivation for its use in another arena. In the following sections some of these uses are described.

Figure 2

2 Urban design history

2.1 Representing the past

Once a model of the contemporary city exists it can be used as the basis for constructing a series of models which trace the development of that city through time. This can be done by using historical records to remove modern buildings and replace them with their predecessors. Given that building plots and street lines tend to remain more or less constant because of land ownership patterns, a technique of backward projection is likely to result in a more accurate model than could be achieved by constructing the whole city from historical sources [4]. With Bath, the aim is to have a city model for each 20 year interval from 1620 to 2000. At the moment only the two end-points exist in 3D although the period between 1620 and 1820 is represented two dimensionally (Figure 3).

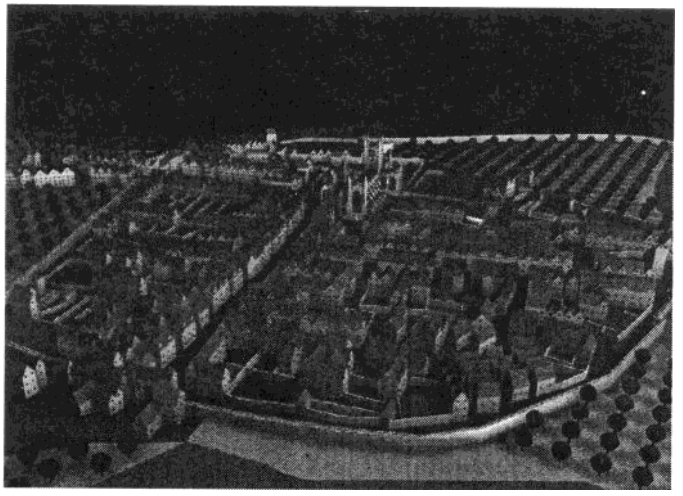

Figure 3

This has allowed animation sequences to be produced which can be run forwards or backwards showing the development of Bath from a small medieval town to a Georgian spa. Where this has been demonstrated publicly it has proved extremely popular and has made urban history explicit in a way that is difficult to match using more conventional presentation methods.

These 3D models are currently being developed so that they can act as an indexing system for historical information, much in the way that maps are used in a geographic information system. Bath is fortunate in having a series of archives on the history of its buildings and residents and there are also a number of local historians who have built up a comprehensive picture of changing land ownership patterns drawn from original leases. At the moment this information is spread around the city in a number of different formats and is very difficult to access. By converting it into a digital format and associating it with individual properties in the city the urban model can be used as a historical database thus making this information much more accessible.

As well as recording what was built in the city, the model can also be used to represent projects that remain unbuilt. In Bath these range from schemes such as John Wood's proposed 'Grand Forum' (adjacent to South Parade) of 1745 [5], to a scheme in 1970 to build a new road under the Georgian core of the city in order to relieve traffic congestion. These 'alternative cities' are more than just curiosities. They acknowledge that the city we see today is only one of a number of possibilities and reaffirm that the city of the future will be determined by investigating and choosing between today's alternatives.

2.2 A database of built form geometry

One advantage of digital information is that it can be distributed very easily and to provide a resource which can be used internationally. Using VRML [6] on the World Wide Web one can explore small 3D models interactively and more complex models can be down-loaded and run locally. It is therefore possible to build up an archive of urban forms which could be used as design precedents or as the basis for design projects in schools of architecture and urban design throughout the world. The Bath model is being used as a prototype for such an archive and will shortly be available at various levels of detail on the Web.

2.3 Testing theory

The reasons why buildings, or parts of a city, were designed in a particular way are a matter for historical investigation. For example, there are a number of interpretations of the antecedents of John Wood the Younger's Circus. Summerson [7] argues that it was based on the Colosseum in Rome and is therefore classically inspired. Hart [8] and Mowl & Earnshaw [9] on the other hand argue that the architecture is an expression of a RomanoBritannic myth and that the whole Circus/Royal Crescent sequence is based on the geometry found in ancient sites, such as Stonehenge and Stanton Drew. These had been studied by Wood as well as the influential English Renaissance architect Inigo Jones. The computer model provides a way of testing this theory by overlaying Wood's survey drawings of Stonehenge, and 3D models of the site, on to the Bath model (Figure 4).

Although such comparisons can be made using paper overlays, the ease with which digital information can be scaled, moved and edited means that the historian can try out many more alternative arrangements and combinations and can compare 3D form as well as plan geometry. Using such a technique Cohn Rowe's thesis [10] that today's plan of Rome is a direct translation of the buildings and spaces of the ancient Rome could be investigated in a way that would be very difficult to achieve using conventional techniques.

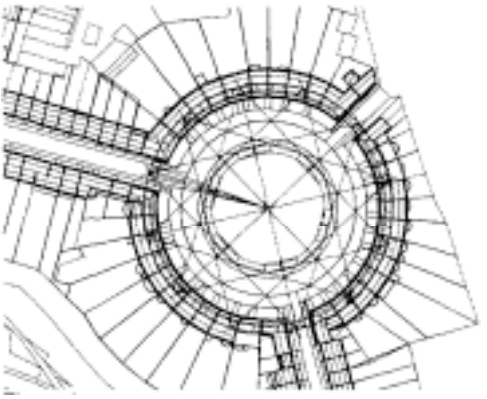

Figure 4

3 Urban design impact

3.1 Representing development proposals

The principal motivation for the construction of the Bath model was the need to better understand the impact of development proposals by placing them in context and viewing them from various positions, near and tar. As a city built over hills, new buildings are often visible from distant and sometimes unexpected locations, and great care is needed to maintain the existing grain and scale of the city. Bad development has commercial as well as aesthetic repercussions; Bath is a major tourist attraction with national and international visitors, and the pleasantness of its streets draws shoppers from a wide region, supporting a much greater range of shops than would be expected in a city of its size.

When the Bath model was originally constructed it was intended that it should be made available to the planners within Bath City Council who could then use it to test the visual impact of contentious planning applications. Each of the 200 sub-models which make up the city can be copied onto a single 3.5" floppy disk and given to an architect to use as a basis for design development. When the design has been completed the altered block can be re-incorporated into the city model. Views and animation sequences can then be set up to see what the proposal would look like from a number of viewing positions. This is a radical change from traditional procedures where views, if any, are normally selected by the applicant and often chosen to show the scheme to best advantage.

In practice, however, the model has not been used in this way and what has happened is that a number of potentially contentious schemes have been identified by the planners and the applicants have the been invited to collaborate with the University in order to visualise the proposal in context. One example of this was an extension to a private girls' school located directly in front of Lansdown Crescent, which stands in a prominent position overlooking the city. The scheme involved the development of a new master plan for the site and the detailed design of a new sports hall for immediate construction.

Although the architects used computers for 2D production drawings they had little experience of 3D modelling and so CASA staff constructed the model and set up the views. This involvement started in the early stages of design development and computer visualisations were used during informal discussions with the planners. They were particularly concerned with the impact of the proposals on views towards Lansdown Crescent from the other side of the valley and on views from Lansdown Crescent over the site to the city below. One particularly attractive feature of the Crescent is the relationship between the loosely curving urban terrace and the idyllic parkland setting which falls away to the south of the crescent and beside which the school is situated.

The planners found the visualisations extremely helpful, corroborating Hall's findings on their usefulness as part of the planning process [11]. The architects, somewhat

to their surprise, also found the computer generated images useful, mainly because they were constructed by a third party and showed their intentions in an objective way. Images and animations produced directly from the computer model were used along with photomontaged images showing new buildings in context (Figure 5).

Figure 5

When the scheme was approved by the planning committee it was the first time that computer visualisation and the Bath model had been used at the request of the planners rather than at the instigation of the client. The use of the model to investigate long distance views of the site was particularly effective in that it clearly demonstrated that the original fears of the planners that the new sports hall would be visually intrusive were unfounded. Not only did this satisfy the planners, it also provided them with objective evidence to substantiate their judgement.

3.2 Models and digital image manipulation

At a time when an impressive image of a proposed development can be produced quite rapidly by taking a photograph of a scene and digitally manipulating that image to show change [12], why should one make a computer model of the whole city of the kind created here? The 'real city is always (necessarily) up to date and contains more detail than any computer model can achieve. It can be captured in a photograph complete with sunshine and shadow, people and cars. Considering the original motive for building the Bath model, that of examining the urban design implications of new building proposals, it seems at first that the aim can be achieved with digital image manipulation alone. Photographs can be taken from various viewpoints and the proposed development can be modelled and 'pasted' into the photographed scene. It is not even necessary to model the proposed building as a three-dimensional object; in many cases elevations which are distorted to appear as perspective images look just as 'realistic'.

A model is needed because, if accurate and respected, it ensures integrity in what is shown. A view taken from the model ensures that relative sizes are correct, that perspective views of the new match that of the existing fabric, and that different views of the same area are consistent. With scanned images alone, imaging very small changes are straightforward (the visual effect of removing or adding signage, for example) and even the addition of a small building that follows an existing street edge can be relatively straightforward. More significant urban change needs a model to keep the image coherent. Any significant demolition is particularly difficult to show through image manipulation alone, because of the need to establish just what will be seen from a viewpoint when a building is removed.

Photographs can only be taken from viewpoints in front of and behind the building to be demolished, but because they are inevitably taken from different points (with consequently different perspective effects), they are essentially incompatible. "Any change in camera position alters perspective, proportion, and relational scale of objects in the view, as these factors are co-dependent on a specifically located point of view" [13].

In contrast, deleting a building from a model to investigate its possible demolition is straightforward, and equivalent views with and without that building can easily be achieved. That does not deny a place for the digitally manipulated image; using the model as a structure for inserting segments of scanned images can work well, where the scanned

image is scaled and manipulated to fit within the overall perspective structure set up by the model. The result is more 'familiar in terms of subtlety of colour changes, detail and texture than can easily be obtained from the model alone, and this can be useful when presenting ideas to an audience unused to the abstractions of computer models. Yet it is always important to recognise the limitations of these kinds of visual simulations, to understand them on their own terms and not as true photographs of a future scene: *"The problem is that owing to the compelling 'reality' of simulations, particularly the photo-real ones, they are often taken as completely accurate, when indeed, they may be* full *of errors. This attribution of accuracy stems from the perception with photographs that the camera never lies. Computer manipulated photographs, however, can significantly misrepresent reality resulting in controversy" [14].*

4 Exploring 'rules' about urban design

4.1 The concept of "rules"

Bath is a city where there are very evident rules about urban design, and where there is real delight in observing subtleties of variations within and re-interpretations of those rules. The English architect Peter Smithson in a booklet entitled "Bath: Walks Within the Walls" observed that "Bath is unique for its embodiment of the romantic-classical dream; for its remarkable cohesion, for a form-language understood by all, contributed to by all" [15]

The articulation and representation of explicit rules for urban development have grown in popularity in the last twenty years. An early well-known example was the 'Essex Design Guide' for new development in the English county of Essex, and now many UK planning authorities have equivalent documents. More recently, the work of ZPK Architects in the United States in setting rules for the development of the small Florida settlement of Seaside [16] and other places [17] has shown how such statements can operate. Many of them refer back to precedents of successful urban forms. In Bath the implicit rules that have governed the form of the existing city provide a starting point for debate about appropriate rules for new work. If new buildings follow the same compositional rules they will 'fit in', in the sense of being essentially similar to the existing buildings. Indeed, following all the rules for designing such buildings should produce 'reproduction' Georgian buildings that may be indistinguishable formally from those around them (although they may stand out as being in remarkably good condition). Equivalent reproduction furniture in historic buildings is common and unremarkable, and many cities have such reproduction architecture, at least skin deep. There are infill developments in the Georgian part of Bath that have followed this strategy.

Describing such rules explicitly provides a basis for better understanding how new buildings relate to old ones. Which rules are broadly followed, and which ignored, in a particular proposal? Are the rules being ignored the really important ones (perhaps the heights of facades, or the vertical emphasis) or secondary (in the Georgian architecture of Bath, perhaps some other means than pilasters for marking the divisions between units)? Are rules being interpreted or extended in new or original ways, for example a treatment of the bays where windows replace pilasters but the rhythm and scale remains the same? Are such extensions and interpretations appropriate? This analysis does not provide a formula by which a design proposal can be judged acceptable or unacceptable, but it will provide a more fruitful basis for discussion and negotiation than do drawings of proposals alone. An urban model allows such ideas to be tested in place within the model, taking more risks in the interpretation and application of the urban design rules that describe a building's formal context than might readily be taken if the result would only become apparent after 'real' construction.

4.2 A streetscape study

Northampton Street in Bath rises steeply up the hill behind Royal Crescent. On its western side a World War II bomb left a gap in its enclosing terrace of houses that has still not been filled (Figure 6a).

The "mock up" of a set of facades allows a study of the relative importance of various compositional rules that contribute to the streetscape and which might be followed in new building. Using a block from the model, the existing gap is filled first by four terrace houses that follow the same rules as the neighbouring buildings: typical Bath Georgian

terrace houses (6b). These four houses are then moved back (6c), exploring the streetscape effect of not respecting the existing building line. With a model it is, of course, easy to view the street from many positions, and not only from a viewpoint on the upper deck of one of Baths open-topped double-deck tourist buses adopted for convenience in these images. Northampton Street, though, is not regarded as one of Baths prime residential streets and the cost of building on this Georgian scale may not currently be feasible.

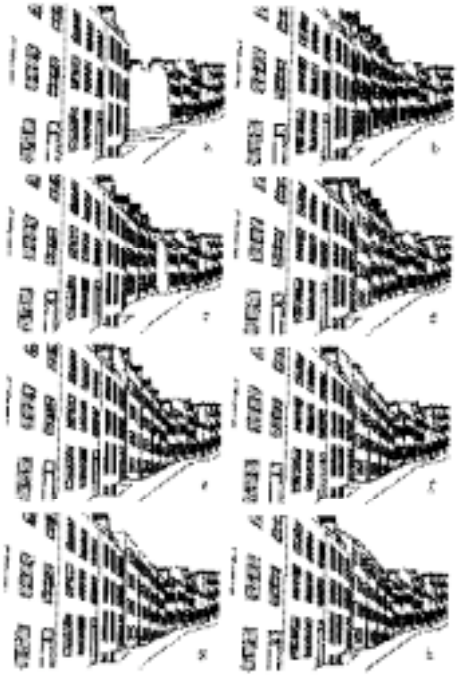

Figure 6

A more common situation is a developers desire to use lower floor-to-floor heights in a new building than were adopted in Georgian architecture, and the next study replaces the three main floors common in the street with four new main floors (6d), while keeping the vertical divisions and the rhythm set up by stepping the level of each building up the street. Such a strategy still implies that each terrace-house unit will be separate, since their floor levels differ. In (6e) they are placed on one level, facilitating their use as combined apartments or offices. In (60 and (6g) the roof detail is reduced, and finally in (6h) projecting eaves are introduced. Projecting eaves are a design element quite foreign to the streets of Bath, and the building contrasts strongly with its neighbours despite respecting the two vital rules of facade height and vertical emphasis. One such contrasting building can appear different and fresh amongst its more conforming company, but each one contributes to the breakdown of the visual coherence that makes Bath special. Such studies are relatively easy to implement given a detailed model of the existing context [18]. Indeed, the existence and availability of the model are encouragements for such studies to take place.

4.3 A game with urban rules

These studies can be regarded as playing games with the model, where it provides the 'game board' for a player to pose scenarios about how the existing city might be interpreted and altered. In 'Growing Georgian Bath' [19] this notion of a non-competitive game is taken further. After compositional analysis, rules were agreed which generated urban form in the style of Georgian Bath at the level of detail apparent in the model. The

game was to add to the city model in a series of independent moves (akin to the original independent moves of the Georgian architect/ developers of Bath), and to see what resulted. There are similarities here to the game described in Christopher Alexander et al's small book A New Theory of Urban Design, where eighteen graduate students played at being architect/ developers in adding to a physical model at a scale of 1/32"=1' (about 1:400): a beautiful model, carefully made, in unpainted hardwood" [20]. Their plays used seven rules to govern development in a simulation, where the rules are guiding principles rather than form generators. The rules used with the Bath model were all directly concerned with formmaking. The game allowed a direct experiment with generative rules on the scale of urban form rather than individual buildings, and showed how two people separately interpreted and used those rules on an interactive design task (Figures 7 & 8).

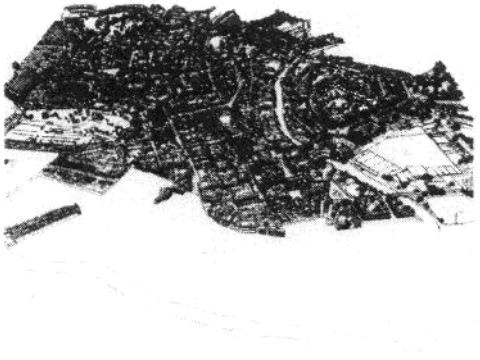

Figure 7

In a small way it suggested how citizens could influence their development of the city by making, discussing and comparing both the rules that could be implemented and the built form that results. Separating the rules from the buildings can be helpful as possible futures can be discussed in abstract rather than by only looking at specific proposals for particular sites.

5 Models and the public perception of change

One of the greatest advantages of using computer visualisation techniques is that they make proposals much more accessibly to non-experts than do traditional drawings and models. Not only do lay people find it difficult to visualise a three-dimensional form from plans, sections and elevations, they also find it difficult to imagine how a new building might look in context. The larger the building the more difficult this is, and when it comes to schemes at an urban scale it can be almost impossible for a lay person to really imagine what is being proposed. In Bath there is an annual event, lasting a week, where the public and local architects are invited to work together in order to propose new developments for the city. Although a World Heritage City, Bath has its share of eyesores, and each year there are a wide range of schemes directed towards addressing these problem sites. Some are conservative, using the language of the existing city to repair damaged areas, while others are more radical, such as a scheme for creating a new lake next to South Parade (Figure 9).

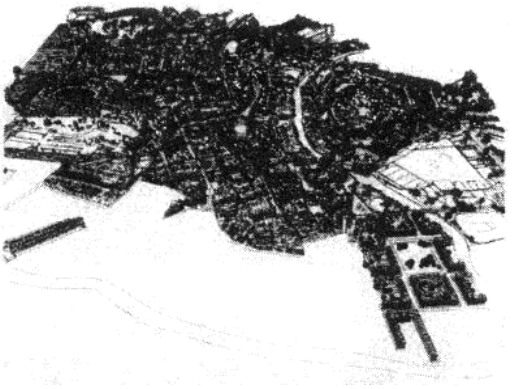

Figure 8

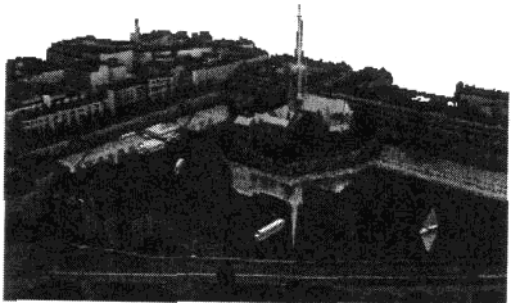

Figure 9

This was proposed by a local architect inspired by John Wood's original intention to create a 'Grand Forum', paved for the most part but with an octagonal lake in the centre. The scheme was modelled and inserted into the Bath model and a series of images and animations produced. These have been exhibited widely in the city, including publication in the local newspaper, and have excited a great deal of interest. It is very unlikely that such a scheme would ever be built but it has helped people realise that the future of Bath need not just be a series of modest neo-Georgian developments mimicking the existing town. Experience of unsuccessful post-war developments has made the people of Bath, and the planners, very conservative and the use of the computer model has had a significant effect in raising peoples' awareness of what might be possible, and in freeing-up 'what-if discussions. The City Council is now interested in using the model in order to create a three-dimensional development plan for a large area of redundant industrial land immediately adjacent to the Georgian core of the city. Under this scheme, it will be used for public consultation as a community design tool to facilitate discussion between designers, planners and users.

The use of images and models as a survey tool has limitations; the world depicted in such images is not equivalent to the 'real world'. Commenting on the use of photographs to assess landscape preferences, Hull and Stewart observe that *"The on-site viewer has a purpose and motivation for viewing the landscape that may be different from the purpose and motivation of a photo-based landscape experience. Moreover, the on-site viewer is experiencing a host of other stimuli including, perhaps, emotions, cognitions and physical fatigue ... the photobased viewer has a very different context."* [21] In researching the public interpretation of computer models of design proposals for a part of Helsinki, Lehtonen [22]

comments on the way viewers sometimes misinterpreted images. She also observes that viewers saw the proposals as inextricable from the surrounding activities and potential consequences, an argument for the comprehensive modelling of the environment as in a city model. Such computer modelling is a much more effective strategy than the available alternatives.

6 Urban design and environmental issues

Research is currently being carried out at the University of Bath into patterns of energy use in the city and, in collaboration with Bath City Council, an energy model is being constructed as part of the UN Agenda 21 initiative on global warming. This model, which maps energy use in the city, provides a way of monitoring change and assessing the effectiveness of energy reduction strategies. The 3D computer model is being used as a way of presenting this information to the public in order to make it more accessible and thus to heighten awareness of environmental issues. A proposal is also being developed to use the model as an interface for a series of decision support tools for examining alternative strategies for accommodating people and cars in the urban environment. One of the problems facing any local authority wishing to tackle such issues is the lack of appropriate tools to predict the implications of alternative design decisions. With sustainability in mind, their aim is to maximise the use of particular transport forms - walking, cycling, and public transport - but to do so in a way that maintains and enhances the appeal of the city to as many potential users as possible. Traditional traffic prediction methods are narrowly defined to maximise flow along particular routes and, as they do not take broader environmental concerns into account, their unthinking application can result in a general degradation of the environment.

In addition to looking at existing arrangements alternative strategies will also be considered. This will be done using the existing computer model of the city linked to the traffic and pedestrian flow models of the kind described by Hillier et al [23]. It will be possible to test some radical ideas and to get a quantifiable measure of the acceptability of these solutions. These might, for example, include the visual intrusion of a massive increase in car parking provision close to the city centre, offset against increased convenience and pedestrianisation; the building of new roads close to the heart of the city, or even the visual effect of increasing numbers of empty shops caused by business closures. The environmental and economic consequences of these alternatives can be presented in parallel with the visual impact.

There is currently a great concern to make existing cities more sustainable. However, in a free society sustainability cannot be imposed, it has to be achieved by consent and that consent implies informed decision making. In order for communities to make such decisions they need appropriate methods for examining alternatives; methods which must be sufficiently accurate while remaining both flexible and easy to comprehend. In the past traffic management has been seen as an arcane art, practised by experts, with the results often mystifying users. This development of the Bath model is about using new technology to demystify that process so that those who are directly involved, as decision makers and consumers, can look at alternative solutions and make decisions that are well founded, not just technically, but also in terms of the more complex subjective and economic factors which are inevitably involved in such a complex issue.

7 Conclusions

Building a computer city model is a major undertaking. Without adequate human, software and hardware resources the time to make and process a large model is a frustrating experience. Moreover, building a computer city model makes necessary an ongoing commitment to maintain and update the model as the software and hardware which constitute the modelling environment changes and the city itself also develops. Unless the model is carried forward, its usefulness quickly declines. As a return on this investment of time and effort, there are great potential benefits. While the future may offer model users a real-time virtual reality experience of the city, even the present relatively time-consuming process of generating individual images from desired viewpoints has no competitors as means for imaging change in a coherent way. A computer city model can therefore become a central and integrating point in discourse about urban growth and change.

8 Acknowledgments

The authors acknowledge the work of Joe Robson (University of Bath) in making and modifying the computer models. Funding for building the computer model of Bath was provided by J. Sainsbury plc and Autodesk. Antony Radford's work at the University of Bath was partially funded by the University of Adelaide Study Leave Scheme. Darren Benger (University of Adelaide) contributed to the section on image manipulation, and Colleen Dunn (CADVantage, Adelaide) modelled the Northampton Street studies.

9 References

[1] This paper took shape while Antony Radford was on leave at the University of Bath from the Department of Architecture, The University of Adelaide, SA 5005, Australia.

[2] Grant, M. P. 'Urban GIS - The Application of the Information Technologies to Urban Management'. in: Powell, J.A. & Day, R., Information Technologies for Construction, Civil Engineering and Transport, (London: Brunel University, 1993, pp.195-199)

[3] Day, A.K. 'From Map to Model: the Development of an Urban Information System', Design Studies, (Vol 15, No.3, pp 366-384)

[4] Alkhoven, P. 'The Reconstructing of the Past: the Application of New Techniques for Visualisation and Research in Architectural History', in: Schmitt, G. N., CAAD Futures '91 Proceedings, (Zurich, 1991, pp.S07-522)

[5] Wood, J. 'An essay towards a description of Bath', (Bath: Kingsmead Press, 1969 - originally published in 1742)

[6] VRML - Virtual Reality Modeling Language

[7]Summerson, J. 'Architecture in Britain 1530-1830', (Harmondsword: Penguin Books, 1955)

[8] Hart, V. 'One View of a Town. Prior Park and the City of Bath', (RES, SpringAutumn 1989, AP 140-157).

[9] Mowl, T. & Earnshaw, B. 'John Wood, Architect of Obsession', (Bath: Millstream Press, 1988)

[10] Rowe, C. & Koetter, F. 'Collage City', (Cambridge: The MIT Press, 1978).

[11]Hall, A. C. 'The Use of Computer Visualisation in Planning Control', Town Planning Review, (64 (2) 1993 ppl93-211).

[12] Mitchell, W.J. 'The Reconfigured Eye: Visual Truth in the Post-Photographic Era', (Cambridge: The MIT Press, 1992).

[13] Decker, J. 'The Validation of Computer Simulations for Design Guideline Dispute Resolution', Environment and Behaviour, (Vol 26 No 3 1994 pp.42l-443); p429.

[14] ibid. p423.

[15] Smithson, P. 'Bath Walks Within the Walls', (Bath: Bath University Press, 1980); p1.

[16] Mohney, D., & Easterling, K. 'Seaside: Making a Town in America' (New York: Princeton University Press, 1991).

[17] Krieger, A., & Lennertz, W. (eds.) 'Andres Duany and Elizabeth PlaterZyberk: Towns and Town-Making Principles' (New York: Rizzoli, 1995).

[18] The mock-ups shown here took about 30 minutes each for an experienced AutoCAD user to model and view.

[19] Radford, A.D., & Day, AK. 'Growing Georgian Bath', Working Paper (Bath: University of Bath Department of Architecture and Civil Engineering, 1994).

[20] Alexander, C., Neis, H., Anninou, A., & King, I. 'A New Theory of Urban Design' (New York and Oxford: Oxford University Press, 1987).

[21] Hull, RB., & Stewart, W.P. 'Validity of Photo-Based Scenic Beauty Judgements', Journal of Environmental Psychology, (Vol.12 pp.101-114); p101.

[22] Lehtonen, H. 'The Ideas of the Visualisation of Plans and the Assessment of Ruoholati', Technical Research Centre of Finland, Helsinki, 1993.

[23] Hillier B., Penn, A., Hanson, J., Grajewski, T., & Xu, J. 'Natural Movement: or, Configuration and Attraction in Urban Pedestrian Movement', Environment and Planning B (Vol 20, 1993) pp.29-66.