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THE APPLICATION OF 3D MODELLING TECHNIQUES IN

BUILT ENVIRONMENT EVALUATION

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Abstract

This paper describes a series of methodologies for use in evaluation of the built environment. The use of virtual models within Architecture and Engineering is widespread at the design stage, but has to date been limited in terms of application and interaction when evaluating the impact of designs on existing environments. Methodologies that have been established in other fields including environmental economics and retail studies were applied, to establish whether such methods were appropriate for use in the built environment. These methods have tended traditionally to use text-based scenarios, potentially causing methodological difficulties where research concerns aesthetic impact. A series of virtual models of existing areas were constructed within CAD and 3D Studio, and through the use of both online and onsite experiments, the capabilities of such models to convey information within experiments was tested.

The research noted that 3D computer models have only rarely been used to facilitate real interaction between interested or affected parties. The paper describes how such models could be applied within public consultation and participation to provide a richer data set.

This research concluded that methodologies including choice experimentation are capable of being completed using imagery as the device for information delivery. It was noted that the use of more interactive virtual environments should be tested in future work.

Keywords: evaluation, visualisation, participation, choice experiments, interaction.

1. Introduction

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 for a more in depth and participatory approach.

Choice experimentation is a relatively recent technique, developed within environmental economics, in which individuals choose their most preferred option from a range of alternatives. Developed from similar methods used within retail studies, choice experiments allow the researcher to identify which attributes and attribute groups the likely user group prefers. Within the built environment, attributes could include for example, paving type, or signage options. A typical experiment would involve individuals being presented with six to ten 'choice sets', each containing a base option and several alternatives, and asked to indicate their preferred option in each set (Blamey *et al*. 1997). Hanley *et al*. (1998) stated that researchers can infer four pieces of information from such experiments, all of which can help predict actual choices that may take place following implementation (or construction):

- the significant attributes;
- the implied ranking of those attributes;
- (in the case of some experiments) the willingness to pay for an increase in significant attributes;
- (in the case of some experiments) the implied willingness to pay for a programme which changes more than one attribute simultaneously.

It should be noted that a 'price' can be included as an attribute, facilitating the estimation of economic values associated with any of the other attributes (Boxall *et al*. 1996). It should be noted also, however, that choice experiments share with the contingent valuation method a concern expressed by many that the inclusion of a 'price' against public spaces can lead to ethical or moral difficulties. Results from the study reported in this paper show that only 5% of respondents said that cost influenced their choices, although additional comments included mention of local authority planning budgets and possible alternative uses for any funds collected. Although the methodology can be defended, care is required on the part of experiment designers to ensure that respondents will not feel disenfranchised due to the manner in which questions are posed.

To convey information, choice experiments describe a 'choice set' using an array of attributes, rather than one specific change to the good or service. Unlike contingent valuation studies, respondents are questioned about a sample of events drawn from the universe of possible events of that type, possibly reducing the incidence to respondents attempting to 'strategically bias' results (Adamowicz *et al*., 1995; Louviere, 1994). As choice experiments are formed using varying levels of attributes, different subsets of goods (including substitutes) are essentially incorporated within their design. This enables researchers to determine an individual's sensitivity to attribute levels thus eliminating embedding problems, and allowing designers to retain control over the possibly inappropriate highlighting of one 'attribute' over another (Adamowicz *et al*. 1995; Morrison *et al*. 1996; Hanley *et al*. 1998).

A potential problem facing many quantitative methodologies is that of respondent burden. Where a research participant is required to simultaneously consider a complex range of variables, there is a danger that complexities in the real environment are lost on the respondent. The fact that CAD models have increasing developed an ability to appear near photo-realistic led the research at an early stage to consider the use of models as the primary method of information delivery and retrieval. Through the use of CAD models, it was felt that there may be an opportunity to present a wide range of variables in a manner which was both easy to understand and which could act as a reasonable surrogate for possible but unbuilt 'actual' environments. This paper describes the manner in which this was implemented, and provides details of current research that will further explore the use of 'realism' and 'visualisation' within built environment evaluation and decision making.

2. Techniques used for visualisation and modelling

The major research questions posed by this research concerned the extent to which visual representations of a space could be used effectively within a choice experiment. Although it is true that many aspects of a space are non-visual to some extent (e.g. temperature, noise), it is also true that a number of prominent recent urban design guides focus very much on making physical changes to space. The methodology, therefore, took as its starting point a decision to impose a cultural scenario on the case study space, within which changes would be made. It was also clear that whatever modelling approach be used that is was possible to vary realistically the model contents.

Results from a series of focus groups (Davies & Laing 2002) were used to provide the basis for a series of design 'solutions', using various combinations of railings, café seating, trees and planters, benches, paving and lighting. The resulting proposed designs were then modelled in AutoCAD, producing a total of 18 unique configurations. The initial CAD model was built up from accurate Ordnance Survey data sets to ensure horizontal accuracy, with building faces extruded in the vertical plane. Additional modelling work was undertaken using 3D Studio Max, and on-site photographic samples were used to provide realistic renderings. A series of high quality visual images were produced for use in the choice experiments, with the contents of each closely controlled to match the experimental requirements. For example, where a particular type of tree was required in a scene, the tree 'model' was virtually placed prior to rendering, and likewise removed from scenes where it was not required. Sample images taken as screenshots from the online experiment are shown in Figure 1.

As it was clear from an early stage in the research that the work should be as inclusive as possible, the decision was taken to run the experiment via Internet browsers. This meant that although gains through the use of CAD/3DS were apparent in terms of static realism, more dynamic approaches to interaction with and alteration of the model would be difficult in real time.

Figure 1. Sample 'screenshot' images taken from the online study

Choice 1 of 9

£2 TAX

Stay the same - £0 TAX

£12 TAX

I prefer: [▾]

Move on to the next choice set

I'm bored - I want to go to the end!!

Figure 1a: Section of the main Internet survey

Figure 1b: Representative "enlarged" images, as provided in the survey

The full study and further details of the project can be accessed via:

http://www.rgu.ac.uk/sss/research/page.cfm?pge=2532

3. Consultation using visualisation and choice experiments

3.1 Methodology

The experiment was completed in two stages, where the main questions were concerned with delivery of the material and control over the technology. The first phase of the study was implemented through an entirely Internet based experiment. The second phase then involved replicating the experiment using a high-end stand-alone machine, thus providing further data to the study as a whole; allowing for a comparison between the two forms of data transfer; and avoiding a number of technical difficulties.

The study was particularly interested in any concerns over download time, image quality, and the operation of various Internet browsers. For example, in order to minimise download times, initially large images were necessarily reduced in size. Although the option was provided to view all images at a larger resolution, doing so inevitably increased the time required completing the questions. In addition, the researchers had no control over the size of screen used by respondents during the Internet phase, meaning that compatibility with most browsers could be programmed but that the survey's final appearance was more difficult to control.

3.2 Results

For the study's initial phase, respondents were required to run the experiment on a computer remote from the research team, and results were written directly to a database stored on the Internet. It was notable that a sizeable number of respondents stated that the images were too similar, that the images were too small, and that the images were too dark. Such comments

suggested that many respondents had looked only at the smaller (thumbnail) images presented on the screen, and did not take time to view the full size scenes. It was also possible that the size of the images could have affected a perception of brightness, or that respondent monitors had not been adjusted during the introductory stages of the experiment. For this study, a test image was included in the introduction and respondents asked to adjust their monitors to optimise brightness and contrast. With regard to the site, some commented that they would have appreciated further information regarding activities, the history of the square and the types of materials used.

The cost variable (willingness to pay) raised interest from respondents (each option was presented with a corresponding tax levy). Although respondents commented that the suggested costs were too high, or that the levels of cost were reasonable, overall only a small percentage (4%) actually felt it influenced their choices. Several other comments were made including that any costs would be difficult to administer; that costs should be proportional to Council tax; and that the payment method proposed was an interesting one.

The second phase of the experiment used a stand-alone machine, with essentially the same questions as the Internet-based study. However, several improvements were made to the questionnaire based on an early analysis the Internet comments discussed above. The main differences between the Internet and the stand-alone studies were the size of the images presented to respondents and the amount of information provided. The stand-alone study was conducted on one computer, which eased control of some problems that occurred in the Internet study. For example, issues stated by respondents concerning individual monitors (such as screen size and brightness) were virtually eliminated. All respondents from the Stand-alone study viewed the study on same monitor (a high quality flat 21-inch screen) and viewed the images at

the same level of brightness/contrast. In addition, the size and resolution of images was much improved.

It was an aim of this research to help reduce cognitive burden (as suggested by Blamey *et al*. 1997) and in parallel drive methodologies to assist the presentation of more complex scenes than is possible using text based methods. Differences in the types of comments made by the Internet and stand-alone respondents suggest that when larger, brighter images are provided (which are quick to download and present on screen), respondents are better able to concentrate on image content rather than on technical issues. This would suggest that using a stand-alone computer is more suitable for presenting detailed images to respondents (due to current average Internet connection speeds) and that some level of text to highlight differences in the images may be required or beneficial.

It was recorded that 26% of the Internet respondents said that the images looked 'very realistic', compared with nearly half (43%) of the stand-alone respondents. The differences in these results could again be a result of monitor size and the ease of opening up larger images on the stand-alone computer, compared to the Internet. Less than 2% of the stand-alone respondents thought that the images looked 'very unrealistic', compared with 5% of the Internet respondents.

4. Proposed collective participation in virtual environments

This section of the paper identifies significant opportunities to establish the use of virtual interactive environments as a tool to better understand interactions and motivations in the real world. Although it is true that what is currently possible using CAD systems with regard to

photo-realism is undoubtedly impressive, it is also true that the same virtual environments must be regarded as a 'next best' surrogate for the actual environment. Where research questions concern the impact of as yet unbuilt structures on the surrounding built environment, though, there is still a strong case for the use of virtual models. Such 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.

A problem with some conventional virtual design research methodology when applied to approximate design solutions arises from the imperative to simulate the real world exactly in order to achieve a 'suspension of disbelief' between subject and object. This in turn prompts the paradox in which the achievement of similitude to the real world may undermine the logical necessity to use a virtual environment in the first place. By using the technology to simulate the built environment experience, rather than the aesthetic (as with 3D Studio models), an innovative and unique forum for social research can be created.

It is suggested that two major issues that concern the issues of realism, immersion and identification of the environment and/or scenario as being 'real' could be explored through the use of alternative and more interactive modelling packages. Firstly, the experience of groups navigating virtual environment models could be explored through groups of respondents providing a continuous and collective feedback, allowing for the possibility of continuous adaptation and improvement. Secondly, communication between group members whilst in the environment could be recorded and analysed. The extent and ways in which communication aids the group in the performance of tasks will be recorded and analysed.

Previous work in non built-environment research has made extensive use of computer gaming technology. Particularly within the field of educational research, the validity and usefulness of computer games has formed a central part of recent methodology. Particular studies have recorded that participants found a high level of 'engagement' in research which explored and recreated in the classroom environment. In a reversal from the traditional view of game media as a mindless and isolating experience for children, educators now hope to explore the extent to which computer games can be used to develop and test personal skills including logic, memory, reflex and mathematics (Dawes & Dumbleton 2002). Preliminary work exploring the potential for using games engine technology as an alternative to 3D Studio models is illustrated in Figure 2. It can be noted that although the level of geometric accuracy in the 'games' model is lower than that in 3D Studio, but that the level of interactivity is greatly enhanced.

Studies from the field of information visualisation (for example, Börner *et al.* 2002) required participants within a virtual environment to complete a series of information gathering tasks, and navigation and communication was recorded as part of the data set. Although such studies are typically concerned with information storage and retrieval, it is proposed that the methodology be extended to concern the collection of qualitative data and in particular data concerning the perceived immersion and realism of virtual worlds. Similarly, previous studies have also set out a theoretical framework for the assessment of the ways in which differing virtual environments can offer genuine feelings of 'presence' to the users (Lombard *et al*. 2000). Richens and Trinder (1999) attempted to utilise the multi-user aspects of games software within the built environment, where that work was geared towards the development of virtual tours of unbuilt structures.

Figure 2.   Sample images taken from games, 3D Studio and photographic studies of

‘The Green’ in Aberdeen, UK.

Figure 2a - composite photograph of a real environment

Figure 2b - ‘3D Studio Max 4’ image, taken from a model of the environment in 2a
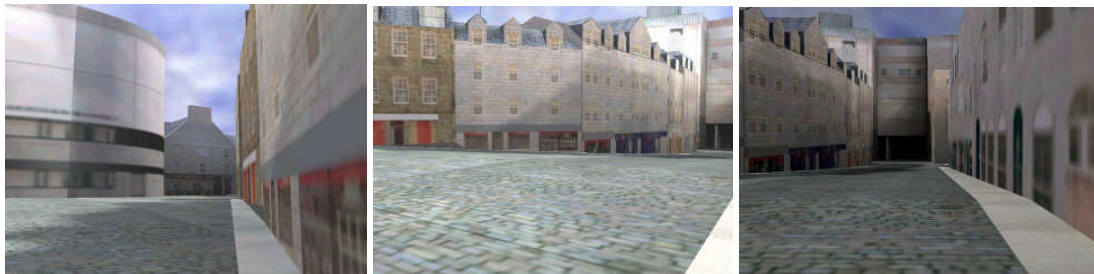

Figure 2c - ‘Quake engine ‘ image, taken from a model of the environment in 2a

Figures 2b and 2c serve to illustrate the extent to which different packages produce similar yet very distinct visualisations.   The rapid rendering and interaction capabilities of the package shown in 2c could arguably balance a loss of geometric detail, in some experiments.

5. Discussion

This paper presents a study that was concerned with the innovative use of CAD models within built environment evaluation. Although a limited number of environmental economic studies in the past have attempted to use images as part of the survey, this study used images to convey almost all aspects of the choice scenario, and also pioneered an automated approach to delivery of the survey. By using a fully computer generated surrogate environment, the researchers were able to realise far greater control over the contents of scenes than if using photographs. Although a number of technical issues required addressing during the study, these were at least in part due to Internet issues, which will ease over time.

It is anticipated that research using immersive and interactive technologies could be used as a tool to highlight or identify those key aspects of an environment, which most critically influence choice and preference. Ultimately, town planners and architects should be allowed to identify the 'sacred cows' of history, heritage, utility and culture against which any change is likely to be judged. This approach might also provide an indication for further research into the interpretation and enhancing of aspects of place to increase the overall attractiveness of an area.

This research has raised a number of important issues which merit further development, with particular regard to the use of computer models. In addition to the application within choice experiments, the research also suggests that greater attention should be paid to the research definition and understanding of 'realism'. Future work, it is suggested, should fully develop the use of interactive environments, within which respondents can demonstrate choice and perception. In this way, the research will ensure that the role of CAD and other models continues

to facilitate rather than hinder meaningful responses within experiments, and provide a foundation for strong conclusions.

6. References

Adamowicz, W., Boxall, P., Williams, M. and Louviere, J. (1995), Stated Preference Approaches for Measuring Passive Use Values: Choice Experiments and Contingent Valuation, Staff Paper 95-03, Department of Rural Economy, University of Alberta, Edmonton.

Blamey, R.K., Rolfe, J.C., Bennett, J.W. and Morrison, M.D. (1997), Environmental Choice Modelling: Issues and Qualitative Insights, Choice Modelling Research Report No. 4, University College, The University of New South Wales, Canberra.

Börner, K., Hazlewood, W.R. and Lin S-M. (2002), Visualising the Spatial and Temporal Distribution of User Interaction Data Collected in Three-Dimensional Virtual Worlds, in, IEEE Computer Society, Sixth IEEE Symposium on Information Visualisation, IEEE Press, 25-31.

Boxall, P.C., Adamowicz, W.L., Swait, J., Williams, M. and Louviere, J. (1996), A Comparison of Stated Preference Methods for Environmental Valuation, *Ecological Economics*, **18**, 243-253.

Davies, A. and Laing, R. (2002), Designing Choice Experiments using Focus Groups: Results from an Aberdeen Case Study, *Forum Qualitative Sozialforschung /Forum: Qualitative Social Research* [On-line Journal], **3**(3), available at: http://www.qualitative-research.net/fqs/fqs-eng.htm

Dawes, L and Dumbleton, T. (2002), Computer Games in Education Project: What Aspects of Games may Contribute to Education?, Project Report, available at: http://www.becta.org.uk/technology/software/curriculum/computergames/

Hanley, N., MacMillan, D.C., Wright, R.E., Bullock, C.H., Simpson, I., Parsisson, D. and Crabtree, R. (1998), Contingent Valuation versus Choice Experiments: Estimating the Benefits of Environmentally Sensitive Areas in Scotland, *Journal of Agricultural Economics*, **49** (1), 1-15.

Kahneman, D. and Knetsch, J.L. (1992), Valuing Public Goods: The Purchase of Moral Satisfaction, *Journal of Environmental Economics and Management*, **22**, 57-70.

Lombard, M., Ditton, T. B., Crane, D., Davis, B., Gil-Egui, G., Horvath, K., Rossman, J. and Park, S. (2000), Measuring Presence: A literature-based Approach to the Development of a Standardized Paper-and-Pencil Instrument. Presented at the Third International Workshop on Presence, Delft, The Netherlands.

Louviere, J.J. (1994), Relating Stated Preference Measures and Models to Choices in Real Markets, paper presented at the DOE/EPA Workshop on Contingent Valuation to Measure Non-Market Values, Herndon, VA.

Morrison, M.D., Blamey, R.K., Bennett, J.W. and Louviere, J.J. (1996), A Comparison of Stated Preference Techniques for Estimating Environmental Values, Choice Modelling Research Report No. 1, University College, The University of New South Wales, Canberra.

Richens, P. and Trinder, M. (1999), Design Participation Through the Internet: A Case Study, *ARQ*, **3** (4), 361-374.

7. Acknowledgements