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The application of visual environmental economics in the study of public preference and urban greenspace

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The application of visual environmental economics in the study of public preference and urban greenspace

Urban greenspace has consistently been argued to be of great importance to the wellbeing, health, and daily lives of residents and users. This paper reports results from a study which combined the visualisation of public greenspace with environmental economics, and which aimed to develop a method by which realistic computer models of sites could be used within preference studies. As part of a methodology which employed contingent rating to establish the values placed on specific greenspace sites, three-dimensional computer models were used to produce visualisations of particular environmental conditions. Of particular importance to the study was the influence of variables including lighting, season, time of day and weather on the perception of respondents. This study followed previous work that established a suitable approach to the modelling and testing of entirely moveable physical variables within the built environment. As such, the study has firmly established that computer-generated visualisations are appropriate for use within environmental economic surveys, and that there is potential for a holistic range of attributes to be included in such studies.

Keywords: Visualisation, environmental valuation, contingent rating, decision support.

1. Introduction

Urban greenspace forms a vital part of the urban fabric, yet rarely generates a direct economic benefit to the community. Furthermore, the manner in which greenspace might be valued by users, residents and interested parties will be influenced by factors, including location, environmental features, design decisions and the background and demographics of the user. This research undertook to explore how methods and results from environmental economics could be used to assess objectively the complex relationship between user, environment and value, whilst making an innovative use of computer-generated visualisations. A contingent rating (CR) method was used to assess the utility of park attributes. The aim of the CR exercise was to assess how variations to physical and non-physical attributes affect perceptions of safety and aesthetic quality, and use of greenspace. The CR approach was chosen over choice experiments, as the study was not concerned with trade-offs between monetary values and physical improvements to greenspace. The overall research methodology centred on the incorporation of spatial and environmental attributes within 3-dimensional models, whilst ensuring that such attributes could be visualised and varied in response to changing environmental conditions including time, season and weather conditions.

Approaches are required by designers and planners of greenspace in the future, to help ensure that public space will be socially sustainable and valued by the intended user groups (for example, Ironside Farrar, 2005). In this study, contingent rating was used to structure the data collection for a survey of the public in Aberdeen. This method provided a mechanism whereby a complex set of ‘attributes’ could be included in a range of computer models, and each scene then ‘rated’ by respondents against set questions and scales. Following previously reported work (Laing et al., 2002), attributes and overall sites were presented using still images taken from photorealistic computer models.

2. Background

It has been accepted and demonstrated that there can be a clear divergence between the opinions and judgements of design professionals and lay people (Hershberger and Cass, 1988; Hubbard, 1997; Nasar and Kang, 1989; Purcell, 1986; Wilson, 1996), which can in turn lead to a lack of user satisfaction (for example, Nasar and Kang, 1989, Newman, 1973). That same body of research has also shown that preferences can also differ among ‘lay people’, and that demographic, economic, cultural and social factors combine to ensure that a coherent generic group does not exist in reality. It has been argued, therefore, that professional judgements may not be relied upon to ensure environmental quality (Hanyu, 1997), not least in the absence of adequate public participation (for example, Hudspeth, 1986; Jones, 1990; Sanoff, 2000). Hudspeth (1986) argued that many projects which have failed or been delayed are also the ones which have excluded public participation. Furthermore, in many cases, these projects have been characterised by heated debate, political controversy and even litigation.

There are a number of general criteria suggested by the European Commission (1996) to facilitate motivation of participants including implementing ‘bottom up’ solutions, relating sustainability issues to aspects of local life, using terminology that the public can understand, emphasising that one person can make a difference, outlining a clear vision for sustainable development and adopting alternative strategies if one approach does not work.

For almost 40 years in the UK, legal stipulations for public involvement in planning have tended to fall short of these aspirations, and despite calls from the Skeffington report (Ministry of Housing and Local Government, 1969) that the public should play a full role in planning matters, this has often in practice resulted in a rather low level of involvement. The planning system has often been criticised for failing to allow the full involvement of non-experts (e.g. Wynne, 1992), and it could be argued gives little more than an illusion of democracy and debate. Furthermore, researchers have argued that planning should be regarded as being inextricably linked with local political discourse (for example, Tewdwr-Jones, 1999). The DTLR (2002) argued that even though there is a lack of data concerning community views and needs (in the UK, at least), such data is essential in developing successful greenspace strategies. They claim that user surveys can determine if, how and when people use greenspace, and their satisfaction levels with what is available, making user surveys crucial in managing and maintaining greenspace.

One approach to providing a common basis with which to assess future environments is the use of visualisation technologies. There is a long tradition of using photographs to investigate environmental perceptions, particularly landscape assessment (e.g. Kaplan et al., 1972; Zube et al., 1982; Brown and Daniel, 1986). The validity of using photographs as surrogates for the real environment has been demonstrated by several authors (e.g. Shuttleworth, 1980; Stamps, 1990), with the proviso that static, soundless representations are unlikely to evoke exactly the same perceptions as would be experienced in the real world. Indeed, Heft and Nasar (2000) demonstrated that the perceptions elicited from dynamic images are often significantly different (i.e. preference ratings are lower) than those elicited from static images of the same environment. Nonetheless, in a review of the relevant research, Daniel and Meitner (2001) conclude that, although caution should be exercised in using photographic representations as surrogates for the real environment, they are a valid methodological tool for much landscape assessment research (for example, Wong and Domroes 2005).

However, an obvious limitation to using photographs in landscape assessment research is that future potential environments can largely only be represented through generic examples, and generally from restricted viewpoints, and there may require to be modifications to the imagery to standardise factors such as overhead conditions. Previous studies have demonstrated that the use of static images to convey the context of landscapes in terms of buildings and layout is valid (recent examples including Ellis et al., 2006; Ryan, 2006) and that the use of computer models to ‘contain’ physical attributes related to landscapes is possible and valid (for example, Appleton et al., 2002).

The use of computer modelling, however, does not restrict the researcher to using images of environments that already exist. Indeed, recent advances in computer graphics means that visualisations of new environments can now be constructed to be accurate, or at least photorealistic, with respect to complex features including lighting, shadows, texture etc. These environments can also be viewed from a multiplicity of viewpoints, or using 360 degree panoramas (Tan et al., 2006). Authors have reported using visualisations in Stated Preference (SP) surveys (e.g. Davies and Laing, 2002; Fukahori and Kubota, 2002), but usually regarding only physical aspects of the environment (e.g. styles of paving, patterns of woodland). The incorporation of non-physical aspects, such as weather or seasons, has been little reported. Rohrmann and Bishop (2002) looked at the effects of lighting (day/sun, day/fog, and night), personal shadow and sound on perceived simulation quality, however to date, stated preference techniques have not been used to make these assessments.

3. Methodology

3.1 Study area

The CR study aimed to elicit views on the reaction of subjects towards greenspaces under different types of designs and environmental conditions, including time of day, lighting, weather conditions, and the presence of people or traffic. To this end, three case study greenspaces were selected within Aberdeen, a city of approximately 220,000 residents located in the north east of Scotland. The areas selected were as follows:

i) Tillydrone (located at the edge of a large local authority owned housing estate);
ii) Aberdeen Links (a linear greenspace located along Aberdeen seafront);

iii) Deeside River walk (a linear greenspace in the city, next to one of the city's two rivers).

The sites were selected to enable consideration of a range of greenspace uses, geographical location, design, content and development pressure; that is, the sites allowed for the study to consider the effects of a range of variables, including enclosure, current use, design, lighting conditions and the presence of traffic and people. It should be noted that selection of the three sites followed the preparation of an inventory of greenspaces, which covered issues including site size, location, accessibility, ecology and facilities. The contents of that inventory were later incorporated within a fully realised spatial decision support system, developed from the research results, including those from the CR study (Laing et al., 2006).

3.2 Feature selection

The CR survey used a questionnaire based on computer generated images. This first required identification of attributes that are deemed important by the relevant stakeholders, and the levels of each attribute. Focus groups were held with local residents living near to these greenspaces. The aims of the focus groups were to discuss views toward individual greenspaces, to discuss any potential changes to the site and to suggest possible choices that might be faced by the designer and user alike. In two of the study sites (Tillydrone and the Links) an option of including paths which cut through each of the sites to encourage use was discussed. For the purposes of this study, new paths have been added to the Tillydrone and Links areas, and the one located at the Deeside River walk has been upgraded. Other physical observations and suggestions arising during focus group discussions for each site included:

- the addition of trees to provide interest and shelter
- adding/upgrading of paths
- adding/upgrading of lighting
- management and reduction of vehicular traffic

- the importance of people being present for reasons of socialising and safety.

Issues which arose across all case study sites were concerns over safety, attractiveness and accessibility. Questions were also posed in the focus groups to determine how changes to non-physical changes such as weather, seasonal attributes, affects perceptions of safety and aesthetic quality, and also if respondents would visit the greenspace shown under the conditions presented. Comments made by participants included observations that ideal (i.e. sunny, well lit, no rain) weather conditions did not truly reflect those experienced most of the time, and that the use and look of the space changed significantly after dark. Based upon the focus group discussions, a number of non-physical attributes relevant to Aberdeen's greenspaces were included in the computer visualisations which were based upon season, weather, time of day and wind.

Using the attributes outlined above, the resulting proposals were modelled in AutoCAD, and rendered in 3D Studio Max (©Autodesk). The model for each site was constructed using Ordnance Survey boundary data from Landline (Ordnance Survey, 2005a) and elevation data (Ordnance Survey, 2005b), with smaller structures (e.g. boat house, skateboard ramp) modelled specifically for the project. Textures for natural surfaces (e.g. grass, snow), trees, bushes and people were taken from available 'collections', in some cases purchased for specific use within the study. This stage of the visualisation required a 'visual' match between the model and the 'real' environment, and in the case of the Aberdeen models a value judgement was made that the trade-off between render time and ecological accuracy was acceptable. As can be observed to some degree from the first pair of images in figure 1 this did not affect key requirements for the visualisation of scale, massing and colour, as the tree models used were largely representative of the arrangement and massing of the 'actual' trees on site. Had the intention of the study been to explore issues of environmental micro-climates, and their effect on tree growth, then a slightly different approach might have been required. However, the time taken to 'grow' virtual versions of the plants would have restricted development of the survey, or to even deal with more than one site. Thus, the approach taken to visualisation and modelling of the site vegetation allowed the research to concentrate on the variation of environmental conditions, without compromising the overall realism of scenes.

Each model was closely controlled in terms of the attributes contained within, and a series of four ‘snapshot’ images was used to represent the site within experimental work.

Figure 1 Example visualisations used in the contingent rating survey

Images on the left are photographs and images on the right are from the models[1].

Deeside case study - the visualisation shows an image from the study with a configuration during winter. The site photograph was taken in late Spring.

Links case study - the visualisation illustrates the inclusion of both lighting and vehicular traffic in the study. The Links is a very open space, with little ambient light after dark from the nearby city outskirts.

Tillydrone case study - the visualisation illustrates the openness of the Tillydrone site. This particular greenspace is provided as general social and exercise space for the housing estate, but contains little in the way of vegetation or facilities. It can also be noted that the site is bounded on three sides by a 9-12ft high wire fence.

3.3 Feature representation

Table 1 shows each of the attributes and levels included in the experimental design. All of these attributes were represented visually in the computer model, as described in the preceding section. Attribute levels were defined in order to represent the range of likely conditions which might be experienced in real life. For example, the four weather conditions which occur most commonly in Aberdeen include clear skies, showers, overcast skies, and local fog. These types of weather therefore make up the four ‘levels’ of the attribute weather.

Table 1. Attributes of greenspaces which were tested and the levels considered in the choice experiment

Attribute	Levels
Site	Tillydrone, the Links, Deeside River walk
Season	Spring, summer, autumn, winter
Weather	Clear, overcast, showers, local fog
Time of day	Morning, afternoon, evening, night

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[1] Further examples from the study, including site walkthroughs, can be found via www.rgu.ac.uk/sss/

Wind	Light to medium, medium to strong
Path	Sealed, unsealed
Lights	Present, not present
New trees	Present, not present
People	Present, not present
Traffic	Light, heavy

Wind was included as an attribute since it plays quite a large role in Aberdeen's weather and could have an impact on how people use greenspace. However, since this attribute is difficult to describe in any detail and difficult to represent visually, only two levels were chosen these being 'light to medium' and 'medium to strong'[2].

Lights, new trees, people and traffic were included as attributes, as these may also play a role in safety perceptions. Specifically, traffic was raised as a safety concern in each of the case study focus groups and is therefore included as an attribute. Traffic is represented in two levels, 'light' and 'heavy', although it should also be noted that vehicular traffic does not actually pass through the case study areas themselves, but is instead routed along the periphery of each. Future studies may feature more interactive computer models and might attempt to better present the movement and sound intrinsic to many environmental attributes.

3.4. Combining images from the models with a contingent rating questionnaire

The attributes were combined according to an experimental design that meets the requirements to estimate the utility function of interest. A total of 96 design alternatives were generated by the contingent rating experimental design[3] and it was decided that each respondent would be asked to evaluate six alternatives each (i.e. two design alternatives from

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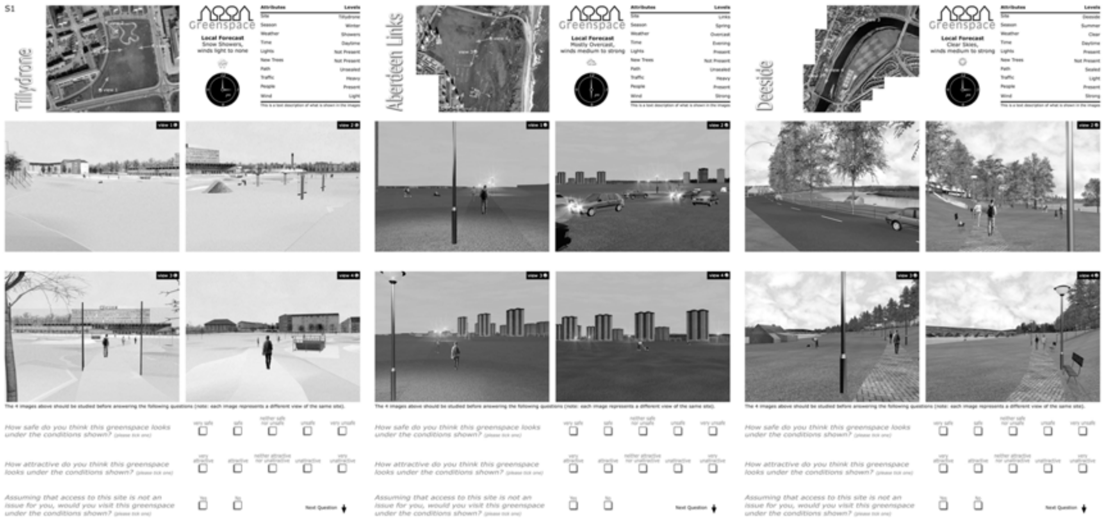
[2] Wind was described using text, rather than as part of the visual image. It is possible that the use of sound could assist with such attributes, and this it is suggested would be a suitable topic for further research.

each case study site, totalling six scenarios). This meant that each respondent would have a reasonable cognitive burden, and that 16 surveys in total were required[4] to produce an acceptable replicate sample for each ‘variation’. Once all 96 models displaying the alternatives had been constructed within 3D Studio Max, four snapshots (or views) from each model were taken for use in the survey, and these presented within each survey to assist with better informed decisions and to facilitate a postal questionnaire. Respondents were then asked to evaluate the profiles on two rating scales. The specific questions asked for each model were “how safe do you think this greenspace looks under the conditions shown?” and “how attractive do you think this greenspace looks under the conditions shown?”. For each question, participants were asked to indicate their response on a five-point scale (very safe, safe, neither safe or unsafe, unsafe, very unsafe), and also asked if they would visit the greenspace under the conditions shown (yes/no), presuming access was not an issue.

Figure 2. Sample pages from the survey questionnaire showing contextual information and visualisations of greenspaces



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[3] Not discussed in this paper.
[4] 6 x 16 = 96

3.5. Pilot study and sample

The sample of respondents consisted of all addresses within the city as listed in the Postcode Address File (PAF), from which every hundredth address was drawn for use, with the survey delivered by post. Respondents were requested to send back the completed questionnaire in a reply paid envelope. The survey was also conducted over the internet and hosted on PCs at public events with Aberdeen. A database was linked to the survey to collect the responses and information downloaded straight into the table, no manual data entry was required.

The CR study was piloted during Aberdeen’s annual ‘Techfest’. The purpose of the CR pilot was to test the questionnaire layout, image quality, length, difficulty, confusion, and background information. Over the course of the event, 54 individuals participated in the pilot study. Respondents were given verbal instructions on the procedure to follow after finishing the introductory pages, and then left alone to complete the study at their own pace, with the researcher available to provide assistance if necessary.

Little assistance was required to aid understanding of the questionnaire, with positive feedback from participants. However, a re-occurring comment made about the questionnaire was in relation to the amount of text provided, with a prevailing view that the introductory pages were too long and should be reduced. Additionally, a number of participants commented that some of the text relating to the attributes and levels represented in the images did not add anything extra to the questionnaire. They thought that most of this information was obvious from the images themselves, especially regarding seasonal changes, day/night scenes and weather conditions.

The time taken to complete the entire questionnaire was approximately 10 minutes. The majority of respondents (73%) said that the questionnaire was either ‘very easy’ or ‘easy’ to understand. Just 5% said it was difficult. In terms of the quality of the images, almost 90% thought they looked ‘very realistic’ or ‘realistic’. It was felt that the electronic pilot study had been very useful in terms of confirming the appropriateness of the survey questions, and that the study would be likely to generate meaningful data. However, it was felt also that there remained a need to control the quality and size of images, and to remove issues of download speed and variable computer qualities.

Therefore, the final and main study used only postal surveys, and were to distributed to 3000 Aberdeen households, with a response rate of 20%. Respondent characteristics are displayed in Table 2. The respondents appear to be quite representative of Scotland except in the age, education, and occupation categories. In the CR study a higher concentration of respondents are aged 35 and 59, are educated to degree level or higher, and work in a professional occupation. These characteristics may be more representative of the population in Aberdeen rather than in Scotland given the nature of the local economy, however statistical information at this level is not easily obtained and therefore is not verified.

Table 2. Characteristics of respondents

	% Study	% Scotland
Sex		
Female	55.6	51.4
Male	44.4	48.6
Age		
15 and under	0.8	19.6
16 – 24	5.8	11.3
25 – 34	15.7	14.6
35 – 44	23.7	15.5
45 – 59	29.7	18.6
60 – 74	18.4	13.7
75 and over	5.8	6.8
Education		
Degree or higher	43.3	16.2
Higher education qualification[1]	17.3	11.7
Higher GCE A level[2]	10.8	29.5
Standard/O Grades or GCSE grades A-C	11.6	17.3
Other qualification	8.7	9.2
No qualification	8.3	15.6
Economically active	62.5	78.5
Occupational group		
Managers & senior officers	12.6	13.9
Professional	38.6	11.6
Associated professional & technical	13.9	13.5
Administrative & secretarial	13.4	13.3
Skilled trades	6.2	12.0
Personal services	3.3	7.1
Sales & customer services	4.4	7.7
Process, plant & machine operatives	2.8	8.5
Elementary occupations	4.9	12.2
Economically inactive	37.5	37.0
Student	13.4	17.9
Other[3]	86.6	79.5
Income[4,5]		
£5 200 or less	9.8	12.0
£5 200 – £7 799	10.3	10.0
£7 800 – £12 999	17.0	17.0
£13 000 – £18 199	13.8	12.0
£18 200 – £23 399	11.6	11.0
£23 400 – £31 199	12.7	13.0
£31 200 – £38 999	7.2	9.0
£39 000 or more	17.6	14.0

4. Results

4.1 Findings in relation to visual images

Several open- and closed-ended questions were included in addition to the contingent rating questions, to give respondents the opportunity to make comments regarding the study, and to provide feedback. The mechanism by which respondents could provide data was important to the validity of the study results, and the survey sought to identify any issues which might have hindered or assisted with clarity of understanding, or influenced responses in some manner.

Table 3. How realistic do the images look?

	% respondents*
very realistic	12.2
realistic	67.7
neither realistic or unrealistic	11.7
unrealistic	7.5
very unrealistic	1.1
Total	100.0

* excluding missing data

From Table 3 it can be observed that the majority of respondents felt that the images were either ‘realistic’ or ‘very realistic’. Interesting non-site specific comments concerned lighting, where the majority of respondents who mentioned this attribute felt that lighting makes places feel safer. Only one respondent commented that lighting could have a negative effect on animals in greenspaces.

4.2 Findings in relation to safety, attractiveness and visits to greenspaces

The CR study provides an econometric framework for analysing how physical and non-physical factors influence people’s perceptions of greenspace. The results for attractiveness and safety are analysed using an ordered logit model since the survey questions asked respondents to evaluate greenspace on likert-type ratings scales. The binomial logit model is used to analyse the visit results as a binomial scale was used. All of the variables in the CR study are qualitative, so they were all effects coded prior to analysis. Limdep 7.0 was used to perform the analysis for the three case study areas and for all sites combined.

Goodness of fit for an ordered logit model can be measured from McFadden's pseudo R^2 (or ρ^2) value. As this was not produced by Limdep, it was calculated from Greene's (2003) formula:

$$\rho^2 = 1 - [\ln L_b / \ln L_0]$$

Where:

L_b = the log-likelihood at convergence

L_0 = the log likelihood at 0

ρ^2 = range of 0 to 1

McFadden's pseudo R2 values for each model are presented in the four tables above. The theory is, as ρ2 increases, the fit of the model improves. Unfortunately however, the values between 0 and 1 have no natural interpretation (Greene, 2003). In this study, they can be used as a guide to determine which models perform better at fitting the data. In each table, the visit models outperform the safety and attractiveness models. The combined sites, Deeside and Links visit models, perform well with ρ2 values of 0.22, 0.27 and 0.22 respectively. The results from the ordered logit regression model for attractiveness and safety, and the results from the binomial logit model for visits, are presented in Tables 4 to 7.

The χ2 values are not used in this study to interpret goodness of fit, as the number of observations (N) included in the analyses are quite large. As such, the probability of rejecting H_0 increases as sample size increases regardless of other factors, and there may be statistical significance when findings are small and uninteresting (Mount Holyoke College, 2002).

The ordered logit procedure is appropriate to use when the parameters ascend in value and are significantly different in value from one another (Austen 1997). This means the following relationship must hold:

$$0 < \mu_1 < \mu_2 < \mu_3$$

The results in Tables 3 to 6 show that the threshold parameters μ_1, μ_2, and μ_3 are highly significant and positive, indicating that the five categories in each of the ordered logit models are in fact ordered, and the correct models for analyses were chosen.

Table 3 shows that nearly all attributes included in the experimental design have a significant[5] influence on attractiveness, safety, and visits, and most signs are as expected. In addition to the combined sites model, site specific models were also produced to see if the effects of the attributes changed depending on the site. This was particularly relevant for the Deeside River walk, as it had the largest effect of all attributes on 'attractiveness', and large effects on 'safety' and 'visits' in the combined sites model. However, major differences in the results were not found between the single and combined sites (see Tables 4 to 7).

Note that in the attractiveness and safety models, a negative coefficient sign increases the probability of a greenspace being rated as attractive or safe, while a positive coefficient sign increases probability of it being rated as unattractive or unsafe. For the visit models, a positive coefficient sign means respondents are more likely to visit when that attribute level is present while a negative sign means the opposite.

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[5] Minimum significance: 10%

Table 4. Ordered Logit results – Combined sites

	Attractive		Safety		Visit	
	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio
Constant	2.889	44.10*	3.071	45.08*	-0.152	-3.85*
Links	0.815	18.06*	0.284	6.59*	-0.229	-4.24*
Deeside	-1.169	-23.97*	-0.430	-9.76*	0.959	16.59*
Tillydrone	0.353	8.10*	0.145	3.35*	-0.731	-13.16*
Spring	0.131	2.50*	-0.013	-0.24	0.017	0.26
Summer	-0.514	-9.54*	-0.470	-8.62*	0.349	5.15*
Autumn	-0.073	-1.37	-0.079	-1.51	0.089	1.36
Winter	0.456	8.50*	0.562	10.31*	-0.456	-6.37*
Rain	-0.110	-2.02**	-0.250	-4.65*	0.124	1.82***
Overcast	-0.146	-2.74*	-0.189	-3.48*	0.230	3.42*
Fog	0.696	12.72*	0.771	14.18*	-0.693	-10.03*
Clear	-0.441	-8.40*	-0.332	-6.38*	0.339	5.08*
Morning	-0.703	-12.68*	-1.052	-18.42*	0.978	14.63*
Daytime	-0.560	-10.18*	-0.653	-11.70*	0.700	10.56*
Evening	0.041	0.75	-0.075	-1.40	-0.050	-0.77
Night	1.222	22.25*	1.780	29.85*	-1.628	-20.85*
Lights	-0.136	-4.41*	-0.132	-4.28*	0.124	3.17*
New trees	-0.201	-6.50*	-0.070	-2.29**	0.141	3.63*
Sealed path	-0.009	-0.29	0.062	2.02**	-0.004	-0.09
Heavy traffic	-0.083	-2.70*	-0.127	-4.12*	0.132	3.34*
Some people	-0.065	-2.12***	-0.163	-5.29*	0.163	4.18*
Strong wind	0.002	0.05	-0.091	-2.95*	0.049	1.23
μ_1	2.645	38.58*	2.712	39.51*		
μ_2	4.396	53.27*	4.228	51.92*		
μ_3	6.542	56.56*	6.379	58.50*		
Log likelihood function value	-4544.296		-4593.014		-2005.668	
Log likelihood function value (Restricted β=0)	-5282.411		-5348.000		-2583.415	
N	3725		3728		3733	
McFaddens's R^2	0.14		0.14		0.22	

* significant 1% **significant 5% *** significant 10%

Table 5. Ordered Logit results – Deeside

	Attractive		Safety		Visit	
	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio
Constant	1.415	9.67*	2.711	26.19*	0.874	11.02*
Spring	0.123	1.25	-0.003	-0.03	-0.156	-1.19
Summer	-0.387	-3.98*	-0.330	-3.45*	0.329	2.35*
Autumn	-0.179	-1.88***	-0.116	-1.25	0.135	1.00
Winter	0.443	4.70*	0.449	4.75*	-0.308	-2.36*
Rain	-0.454	-4.49*	-0.452	-4.63*	0.480	3.40*
Overcast	-0.254	-2.62*	-0.087	-0.89	0.286	2.07**
Fog	1.243	11.97*	0.840	8.98*	-0.971	-7.78*
Clear	-0.535	-5.59*	-0.301	-3.23*	0.205	1.54
Morning	-0.985	-9.23*	-1.174	-11.20*	1.288	8.35*
Daytime	-0.751	-7.45*	-0.789	-8.21*	0.891	6.08*
Evening	0.036	0.36	-0.183	-1.92***	-0.105	-0.86
Night	1.700	16.02*	2.146	19.32*	-2.073	-15.92*
Lights	-0.007	-0.13	-0.015	-0.27	-0.011	-0.15
New trees	0.094	1.68***	0.092	1.70***	-0.089	-1.16
Sealed path	-0.037	-0.66	0.070	1.28	-0.014	-0.19
Heavy traffic	-0.136	-2.41*	-0.140	-2.54*	0.151	1.88***
Some people	0.074	1.31	-0.118	-2.17**	0.045	0.59
Strong wind	-0.031	-0.56	-0.216	-3.95*	0.047	0.59
Employed	0.547	3.45*	-	-	-	-
Retired	0.687	3.71*	-	-	-	-
μ_1	3.014	26.19*	2.782	25.10*		
μ_2	4.735	30.72*	4.330	30.79*		
μ_3	6.717	26.68*	6.4606	32.95*		
Log likelihood function value	-1334.352		-1467.528		-577.6400	
Log likelihood function value (Restricted β=0)	-1574.873		-1749.339		-795.8091	
N	1241		1242		1240	
McFaddens's R^2	0.15		0.16		0.27	

* significant 1% **significant 5% *** significant 10%

Table 6. Ordered Logit results – Tillydrone

	Attractive		Safety		Visit	
	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio
Constant	3.204	23.67*	3.249	24.69*	-0.710	-9.33*
Spring	0.166	1.81***	0.094	1.01	0.053	0.45
Summer	-0.643	-6.82*	-0.500	-5.17*	0.323	2.90*
Autumn	0.048	0.52	-0.069	-0.78	-0.035	-0.31
Winter	0.429	4.59*	0.475	4.97*	-0.341	-2.68*
Rain	-0.003	-0.03	-0.384	-4.05*	0.008	0.07
Overcast	-0.249	-2.69*	-0.282	-3.08*	0.431	3.86*
Fog	0.640	6.68*	0.884	9.16*	-0.611	-4.84*
Clear	-0.389	-4.35*	-0.217	-2.35*	0.172	1.53
Morning	-0.621	-6.62*	-0.935	-9.55*	0.612	5.63*
Daytime	-0.416	-4.29*	-0.614	-6.15*	0.543	4.89*
Evening	0.027	0.28	-0.024	-0.26	-0.057	-0.49
Night	1.009	10.57*	1.573	15.34*	-1.099	-8.33*
Lights	-0.346	-6.40*	-0.322	-5.89*	0.323	4.81*
New trees	-0.254	-4.72*	-0.101	-1.90***	0.209	3.14*
Sealed path	0.063	1.20	0.041	0.77	0.041	0.62
Heavy traffic	-0.138	-2.59*	-0.220	-4.11*	0.208	3.05*
Some people	-0.065	-1.22	-0.181	-3.36*	0.149	2.20**
Strong wind	0.000	0.00	-0.087	-1.63	0.061	0.90
Retired	-	-	0.319	2.40*	-0.415	-2.61*
μ_1	2.554	19.48*	2.772	21.25*		
μ_2	4.417	29.09*	4.385	28.91*		
μ_3	6.617	31.76*	6.595	33.68*		
Log likelihood function value	-1543.143		-1521.639		-696.2353	
Log likelihood function value (Restricted β=0)	-1691.148		-1753.358		-791.2419	
N	1237		1242		1240	
McFaddens's R^2	0.09		0.13		0.12	

* significant 1% **significant 5% *** significant 10%

Table 7. Ordered Logit results – Links

	Attractive		Safety		Visit	
	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio
Constant	3.744	23.06*	3.379	25.89*	-0.446	-6.00*
Spring	0.081	0.94	-0.133	-1.50	0.183	1.60
Summer	-0.519	-5.52*	-0.591	-6.21*	0.501	4.09*
Autumn	-0.079	-0.84	-0.053	-0.57	0.173	1.48
Winter	0.517	5.43*	0.776	8.15*	-0.857	-6.10*
Rain	0.062	0.67	0.081	0.89	-0.082	-0.66
Overcast	0.016	0.18	-0.239	-2.54*	0.005	0.05
Fog	0.344	3.54*	0.668	6.87*	-0.546	-4.43*
Clear	-0.422	-4.63*	-0.510	-5.71*	0.622	5.23*
Morning	-0.612	-6.54*	-1.111	-11.51*	1.177	10.05*
Daytime	-0.655	-6.81*	-0.627	-6.38*	0.760	6.60*
Evening	0.061	0.65	-0.048	-0.51	-0.110	-0.95
Night	1.206	12.49*	1.787	17.18*	-1.827	-11.50*
Lights	-0.080	-1.51	-0.070	-1.33	0.063	0.91
New trees	-0.418	-7.65*	-0.206	-3.81*	0.296	4.34*
Sealed path	-0.033	-0.62	0.084	1.59	-0.047	-0.70
Heavy traffic	0.021	0.39	-0.025	-0.46	0.114	1.54
Some people	-0.168	-3.16*	-0.210	-3.94*	0.305	4.37*
Strong wind	0.028	0.52	0.019	0.36	-0.062	-0.853
μ_1	2.653	17.01*	2.713	21.07*		
μ_2	4.429	25.94*	4.213	28.62*		
μ_3	6.605	32.60*	6.415	33.78*		
Log likelihood function value	-1572.398		-1545.785		-671.4820	
Log likelihood function value (Restricted β=0)	-1731.298		-1805.353		-857.2494	
N	1247		1248		1251	
McFaddens's R^2	0.09		0.14		0.22	

* significant 1% **significant 5% *** significant 10%

Looking at the individual sites in Tables 5 to 7, *night* has the biggest influence on attractiveness, safety and visits. The coefficient sign is positive in the safety and attractiveness models, meaning that alternatives that include this attribute are more likely to be rated unsafe and unattractive. Respondents are also less likely to visit during this time. *Morning* and *daytime* increase the probability of all three single sites and the combined sites being rated as attractive and safe, and have positive effects on visits. *Evening* is only significant in the safety model for the Deeside River walk. The negative coefficient sign suggests this attribute level increases the probability of it being rated safe.

In terms of season, *summer* and *winter* have the largest effects on each of the combined sites models and the single site models. *Summer* is negatively signed in each case, meaning that alternatives with this attribute are more likely to be rated as attractive and safe. Respondents are also more likely to visit during this time. As expected, *winter* has the opposite effect to *summer*. *Autumn* is only significant in the Deeside model and increases the probability of this site being rated as attractive. *Spring* increases the probability of the combined sites and Tillydrone and being rated unattractive.

Looking at weather, *fog* has a large effect on attractiveness, safety and visits to each single site as well as to the combined sites. Alternatives displaying this attribute are more likely to be rated unattractive and unsafe. It has a negative effect on visits. *Overcast* is found to increase the probability of the combined sites and Tillydrone alternatives being rated as attractive and safe, and has a positive effect on visits. It increases the probability of the Deeside River walk being rated attractive and has a positive effect on visits, and it increases the probability of the Links being rated as safe.

A priori expectations for *showers* were that it would reduce the probability of greenspace being rated as attractive, safe and would have a negative impact on visits. However, *showers* increase the probability of the combined sites and the Deeside River walk being rated attractive and have a positive effect on visits. It also increases the probability of the combined sites, the Deeside River walk and Tillydrone being rated as safe. *Clear* increases the probability of the individual site and combined sites being rated attractive and safe. However, it only has a positive effect on visits in the combined sites and Links 'visit' models.

Lights increase the probability of the combined sites and Tillydrone being rated as attractive, safe, and have a positive effect on visits. *Lights* are insignificant in the Deeside River walk and the Links models.

Adding *trees* to the combined sites, Tillydrone and the Links models increases the probability of them being rated attractive, safe and has a positive effect on visits. A priori expectations however, suggest that trees are likely to make greenspace feel less safe as they can restrict visibility. This only occurred at the Deeside River walk, where *trees* increase the probability of it being rated unsafe, as well as unattractive. A possible explanation for this result is that few trees exist at the Links and Tillydrone already, so adding trees to these areas is seen as a positive change. On the other hand, there are existing trees along the Deeside River walk. Therefore, adding more trees will reduce visibility in the area, thereby making it appear less safe and possibly less attractive as the views will be restricted. A path was included in the experimental design based on the findings of the focus groups held with local residents. A priori expectations were that a *sealed path* would be preferred to an *unsealed path* in each of the sites for both aesthetic and safety reasons. A *sealed path* does increase the probability of the combined sites being rated safe, but is not significant in any other model.

Traffic and *people* were included in the experimental design mainly to test their effects on safety in and around greenspace. *Heavy traffic* increases the probability of the combined sites, the Deeside River walk and Tillydrone being rated as attractive, safe, and has a positive effect on visits. Having *some people* visible increases the probability of each single site and the combined sites being rated safe, and the combined sites and the Links being rated attractive. It has a positive effect on visits to the combined sites, the Links and Tillydrone. *Wind* was included in the experimental design as it is a prominent feature of Aberdeen's weather and could affect how people use greenspace. However, this attribute appears is only significant in the combined sites and Deeside River walk safety models, where it increases the probability of them being rated safe. In terms of additional attributes affecting responses, being *employed* or *retired* increases the probability of Deeside being rated unattractive, and *retired* increases the probability of Tillydrone *rated unsafe and reduces visits to this site.*

4.3 Marginal effects

According to Austen (1997) and Huang et al. (2000) the estimated coefficients in ordered logit models should be interpreted in terms of the probability of a certain category being selected. This interpretation can be obtained by calculating the marginal effects, which is done via differentiation. Note, the sum of the marginal probability of selecting any of the five categories of attractiveness or safety from Tables 8 and 9 equals zero as increasing the probability of one category is offset by decreases in other category(s) (Huang et al., 2000).

Table 8. The marginal effects for attractiveness for all study areas combined

	Very attractive [y=0]	Attractive [y=1]	Neither [y=2]	Unattractive [y=3]	Very unattractive [y=4]
Constant	-0.143	-0.568	0.278	0.361	0.072
Links	-0.040	-0.160	0.078	0.102	0.020
Deeside	0.058	0.230	-0.112	-0.146	-0.029
Tillydrone	-0.017	-0.070	0.034	0.044	0.009
Spring	-0.007	-0.026	0.013	0.016	0.003
Summer	0.025	0.101	-0.049	-0.064	-0.013
Autumn	0.004	0.014	-0.007	-0.009	-0.002
Winter	-0.023	-0.090	0.044	0.057	0.011
Precipitation	0.005	0.022	-0.011	-0.014	-0.003
Overcast	0.007	0.029	-0.014	-0.018	-0.004
Fog	-0.034	-0.137	0.067	0.087	0.017
Clear	0.022	0.087	-0.042	-0.055	-0.011
Morning	0.035	0.138	-0.068	-0.088	-0.018
Daytime	0.028	0.110	-0.054	-0.070	-0.014
Evening	-0.002	-0.008	0.004	0.005	0.001
Night	-0.060	-0.240	0.118	0.153	0.031
Lights	0.007	0.027	-0.013	-0.017	-0.004
New trees	0.010	0.040	-0.019	-0.025	-0.005
Sealed path	0.000	0.002	-0.001	-0.001	0.000
Heavy traffic	0.004	0.016	-0.008	-0.010	-0.002
Some people	0.003	0.013	-0.006	-0.008	-0.002
Strong wind	0.000	0.000	0.000	0.000	0.000

Table 9. The marginal effects for safety for the all study sites combined

	Very safe [y=0]	Safe [y=1]	Neither [y=2]	Dangerous [y=3]	Very dangerous [y=4]
Constant	-0.128	-0.613	0.176	0.459	0.107
Links	-0.012	-0.057	0.016	0.042	0.010
Deeside	0.018	0.086	-0.025	-0.064	-0.015

Tillydrone	-0.006	-0.029	0.008	0.022	0.005
Spring	0.001	0.003	-0.001	-0.002	0.000
Summer	0.020	0.094	-0.027	-0.070	-0.016
Autumn	0.003	0.016	-0.005	-0.012	-0.003
Winter	-0.023	-0.112	0.032	0.084	0.020
Precipitation	0.010	0.050	-0.014	-0.037	-0.009
Overcast	0.008	0.038	-0.011	-0.028	-0.007
Fog	-0.032	-0.154	0.044	0.115	0.027
Clear	0.014	0.066	-0.019	-0.050	-0.012
Morning	0.044	0.210	-0.060	-0.157	-0.037
Daytime	0.027	0.130	-0.037	-0.097	-0.023
Evening	0.003	0.015	-0.004	-0.011	-0.003
Night	-0.074	-0.355	0.102	0.266	0.062
Lights	0.006	0.026	-0.008	-0.020	-0.005
New trees	0.003	0.014	-0.004	-0.011	-0.002
Sealed path	-0.003	-0.012	0.004	0.009	0.002
Heavy traffic	0.005	0.025	-0.007	-0.019	-0.005
Some people	0.007	0.033	-0.009	-0.024	-0.006
Strong wind	0.004	0.018	-0.005	-0.014	-0.003

Given the similarities in both the attractiveness and safety models in particular, a correlation test was performed on the three dependent variables. The test reveals significant correlation between each pair of variables. This suggests, for example, that respondents who rate an alternative as safe, also rate it as attractive and would visit under those conditions. Jorgensen et al. (2002) had similar findings. Respondents from their urban forestry study gave images similar ratings in terms of safety and preference. They suggest the finding could be due to the relationship between concepts of safety and preference, and that some respondents find it difficult to distinguish between the two.

In the CR study, it may be possible to test whether the correlation is reflective of asking three questions per alternative, or whether the attributes do in fact cause similar responses, regardless of which question is asked. The study could be conducted again, asking each respondent one of the CR questions instead of all three. The correlation test could be reapplied. If it no longer exists, the correlation may be the result of the types of questions rather than difficulties in distinguishing between the different concepts as suggested by

Jorgensen et al. (2002). However, an even larger sample size would be required to carry out the test making it unfeasible for the purposes of this research.

The largest increases in marginal probabilities in both the attractiveness and safety models occur mainly in the y=1 and y=3 columns. This reflects the likelihood that people tend to ignore the extreme categories in rating type exercises.

The remaining columns y=2 (neither attractive nor unattractive), y=3 (unattractive) and y=4 (very unattractive) can be interpreted as follows. In table 8, *night* produces the largest marginal effects. This means that *night* increases the probability that respondents will rate an alternative as 'unattractive' by 0.153 for the combined sites. *Fog* decreases the probability of respondents rating an alternative as attractive to very attractive by 0.171 while increasing the probability of it being rated unattractive to very unattractive by 0.104.

Looking at safety in table 9, *morning* has the largest marginal effect on y=0 (very safe) and y=1 (safe). *Morning* increases the probability an alternative will be rated 'very safe' and 'safe' by 0.044 and 0.210 respectively for the combined sites. *Night* has the largest marginal effect on y=2 (neither safe nor unsafe), y=3 (unsafe), and y=4 (very unsafe) with values of 0.102, 0.266 and 0.062 respectively for the combined sites, and *daytime* increases the probability of an alternative being rated safe or very safe by 0.157. *Fog* increases the probability an alternative will be rated unsafe to very unsafe by 0.142 for the combined sites, and *winter* increases the probability of respondents rating an alternative as unsafe to very unsafe by and 0.104 for the combined sites.

5. Discussion

The research reported in this paper seeks to assess how variations to physical and non-physical attributes affect perceptions of safety and aesthetic quality, and use of greenspace.

The visualisation materials used in the survey aimed to provide an understanding of how a holistic presentation of the environment could be modelled. Key questions facing designers and planners will often be more than physical change, towards a requirement to understand how space might be used, perceived and regarded throughout the year (Ironside Farrar 2005).

The main findings of the visualisation study focus on feedback to those visualisations, and the extent to which they were accepted by respondents as a valid foundation for stated decisions and choices. Responses to the closed questions in the survey were also offered concerning the realism of the images, and in addition to those responses in Table 3, some commented that the images made the sites appear far better or ‘cleaner’ than they are in reality, with no litter apparent from the survey forms. Comments were also made concerning the images of people and the consistency of the imagery with respect to the environmental conditions being represented (particularly when snow was being presented). As the imagery of the people was kept constant throughout the questionnaire, those portrayed in the snow scenes were wearing inappropriate clothing for the conditions and time of year. There is no quantifiable effect of such inconsistencies on the results of the surveys, however it is recognised as a potential difficulty faced by the methodology, and merits further research.

The research also raised other issues which merit further investigation. Whilst the results confirm that the use of ‘virtual’ environments holds potential for greater application within environmental economics, it is also probable that work using more immersive or interactive technologies for the delivery of data to respondents could offer a tool to identify more objectively key aspects of an environment. Such environments have been tested in previous studies (for example, de Kort et al., 2003) the results of which suggest a capability for conveying an enhanced sense of landscape experience compared with those of static images and photographs and thus a role to play in research and information exchange with respect to changes in green and open spaces. It is likely that the experience of movement through an environment, and the movement of objects within that environment, may play an important part in perception and the formulation of choices (Bishop et al., 2001, Willis et al., 2004). Therefore, future research could consider the extent to which landscape valuation studies, including choice experiments and contingent rating studies (e.g. developing on the work of Dijkstra et al., 2003), can utilise such technology, retaining necessary controls over experimental rigour but properly exploring the relationships between those attribute sets programmed within a virtual model and the manner in which landscapes are perceived and understood by subjects.

Technical developments in recent years have also seen the visualisation capabilities of widely available desktop software increase in realism, usability and speed. This has happened coincidentally with considerable improvements in the availability and speed of internet provision, and the use of web-based services to support applications including gaming and streaming media. Studies such as that reported in this paper could benefit from delivery through the internet, although a potential widening of the respondent base would require careful balancing against needs for adequate demographic controls, and a need to ensure the quality of materials as they are actually viewed at remote sites on equipment which could not be easily calibrated or approved by the research team. Recent work by the research team (Laing et al., 2007), for example, tested the extent to which desktop based visual presentations of historic public spaces could act as a surrogate for research purposes, and found the results to be encouraging in terms of respondent feelings of immersion. That study also found that allowing respondents the ability to actively ‘move’ within a virtual space provided deeper feeling of having visited a place than where they were asked to participate as non-involved spectators. Through the use of such technology, or indeed the use of larger scale and semi-portable VR presentation installations, it should be possible to explore such technical avenues for research in the future.

The issue of landscape design and a perception of lack of safety, is a vital area for further research. Indeed, recent studies have continued to show that there is a need to recognise the balance between the facility afforded by certain types of landscape, fear of assault (for example, Jorgenson et al., 2006), and the potential for such landscapes contributing to increased social cohesion (Greenspace Scotland 2004). Similarly, other studies which focussed on the environmental and aesthetic implications of design choice in urban greenspace have identified a need to balance apparently natural and man-made features, on the basis that residents of dense urban centres place great value on what public open space might be available (for example, Lo et al., 2003). This research has shown that a suitable balance between physical and environmental features will vary between sites, but that the likely levels of perceived attractiveness, safety and desire to visit can be related to site attributes. The methodology presented in this paper provides a potentially valuable tool for the designer and planner. This is particularly true given the capabilities of the system, with its associated stages of public participation, to capture and then test reaction to designed scenarios. Although certain variables (e.g. weather, season) are outwith the control of a designer, such environmental constraints will greatly influence the perceived safety, attractiveness and affordances provided to a user by an area of green or other public space. By testing the likely perception of greenspace areas under such variable conditions, it may be possible to produce a richer and more appropriate form of designed environment, where users are properly involved as participants in the design process.

6. Conclusions

This research has demonstrated how advances in visualisation techniques and desktop capabilities have facilitated step changes in what is possible with regard to methods open to the researcher in environmental economics. It embraced a need to collect, analyse and understand complex data in a manner and form which could then be utilised to determine future policy and guide greenspace planning. The approaches described in this paper collectively provide a methodology through which the attitudes, opinions and values of end users can be understood and integrated within strategies and local plans.

In the contingent rating study, additional trees positively affected perceptions of safety and attractiveness in most cases, with the exception of along the Deeside River walk. This research suggests that while adding trees to urban space is generally considered positive, care has to be taken so that visibility is not compromised (this is consistent with Ulrich 1986).

While many built environment preference studies exist, few have used stated preference techniques such as those described in this paper. In many cases, preference studies are undertaken but the techniques used tend to look at an environment as a whole, rather than determine the trade-offs between individual attributes. The benefit of using stated preference techniques such as contingent rating is that the relative importance of individual attribute levels on the resource being evaluated can be derived. The studies which do frequently employ stated preference techniques are usually carried out in the natural environment by environmental economists. Therefore, this research attempted to address a need to test the applicability of stated preference techniques in the built environment, and the positive results suggest that further applications would be appropriate.

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