Managing scenic resources: modelling natural landscape preferences

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Abstract

As scenic resources worldwide are depleted, it is necessary to find ways to protect, manage and enhance those areas which remain. In order to prevent further loss, methods of minimising negative change and enhancing already degraded landscapes must be found. It is therefore critical to know how to quantify "scenic" and how the general public perceives these landscapes.

One approach to this problem is to produce a mathematical model which can predict the general public's preferences for a number of landscapes. This paper will chronicle the creation of such a model, from the collection of preference data for a known set of landscapes, the analysis of those landscapes, to the testing of the model and its application to a hypothetical change in landscape.

Keywords: landscape, preference, scenic, Scotland

1 Introduction

This work is part of a PhD project into techniques for natural landscape evaluation; the aim of this project is to produce a planning aid to assist those wishing to alter the landscape, or study its change, to do so in a manner sensitive to the perceived scenic qualities of the landscape. Such an aid would help in monitoring the scenic and cultural qualities of the landscape in both the present and the future with respect to potentially deleterious landscape changes.

If a landscape is to be altered, it is important to be able to visualise that change and model how a negative affect can be minimised to alleviate a decline in the scenic quality of the landscape. If the general public's preference for landscape can be quanitified, then their relative preference for a changed landscape may also be quantified and compared. The development of a landscape scenic preference model will allow such 'scores' to be assigned.

This paper describes the creation of a predictivelandscape preference model, from inception to application. Firstly, the thought process that must be gone through before any data gathering can begin, are discussed. Secondly, the methodology for data gathering is noted and alternative methods suggested. Finally, the statistical creation of the model itself is stated and discussed.

The model that will be created is based on ideas used in the work of Shafer et al. (1969); the model will be a psychophysical model: using preference data gathered from people (the psychological data) with landscape component data, objectively measured from photographs of the landscape (the physical data); and relating the former to the latter in a mathematical manner.

2 Model genesis

Before attempting to create a predictive preference model, several matters need to be considered. The rationale behind the model must be addressed, and the motives for creating the model examined. The equipment which will be required to make the model is detailed, this depends heavily on the methodology employed to undertake the survey. Finally, it is necessary to consider the samples used: both geographical locations of landscapes and the sample of respondents to be used. This paper will discuss the creation of a preference model using the Internet to collect the initial preference data. Other methods will be only briefly mentioned.

Reference will be made to research undertaken by the author where appropriate, and details of the creation of a landscape preference model by the author will be denoted by shaded text boxes.

2.1 Equipment required

The equipment needed to create a landscape preference model is detailed below:

- Camera (SLR or 35 mm film compact camera with 35 mm or 50 mm focal length)
- Scanner (capable of 200 dpi (dots per inch))
- Alternatively Digital Camera (capable of 640 by 480 resolution and 16 bit colour)
- Computer (any platform) with suitable graphics and text editing packages
- WWW Server
- Geographical Information System (GIS) (optional)

It is important to use the same equipment throughout the gathering of the photographs and the graphic editing. If print film is used, the same brand must be used throughout the research; the same or similar cameras should be used throughout and the focal length and field of depth settings should on no account be altered. Software drivers, for example on the scanner, should remain identical, even if faster, more efficient products become available.

2.2 Model rationale

Before starting any fieldwork or analysis it is necessary to determine why the model is needed. If it is for a specific purpose then it may require a selection of landscapes tailored to that purpose, for example, the model may be required to assess changes to fairly low elevation agricultural landscapes, in which case mountain scenes are not relevant to the study.

Alternatively, the model may be used generically for a wide range of landscape types, in which case there should be as wide a geographical range as possible. In this case, the width of this region needs to be determined; in terms of Scotland, is just Grampian large enough, or is the whole country required? Is the model looking at a specific type of Scottish landscape, such as arable farms within the Grampian region? Once these questions have been answered, the geographical region within which photographs can be taken can be defined.

The model was required to be generic to the Scottish landscape, therefore requiring samples to be taken throughout the country. The map below (Figure 1) demonstrates where these sites were in Scotland.

2.3 Respondent sample

As well as determining the type of landscapes needed, the sample needs to be considered. Is the survey going to look at the preferences of the people within the region used, or will a world-wide sample suffice. If the sample is required to be representative of the general public, rather than the general 'Internet public', it may be more beneficial to use a traditional paper-based questionnaire instead of an Internet based survey.

As this research focuses on methodology rather than the model output, it was decided that a world-wide Internet sample would suffice. It was accepted that this sample would not be representative of the general public. The Internet general public differs from the standard general public in several ways: age groups and gender ratios are particular examples. It should also be remembered that occupations will differ significantly between the two groups, and that certain socio-demographic classes will be over-represented.

Figure 2 illustrates the geographic areas from which responses were gained.

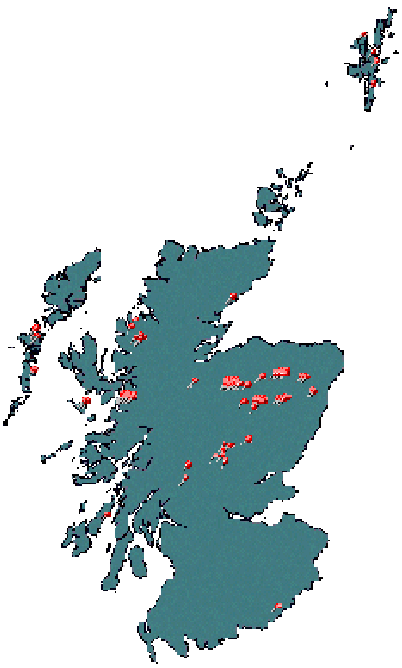


Figure 1. Map of sites in Scotland.

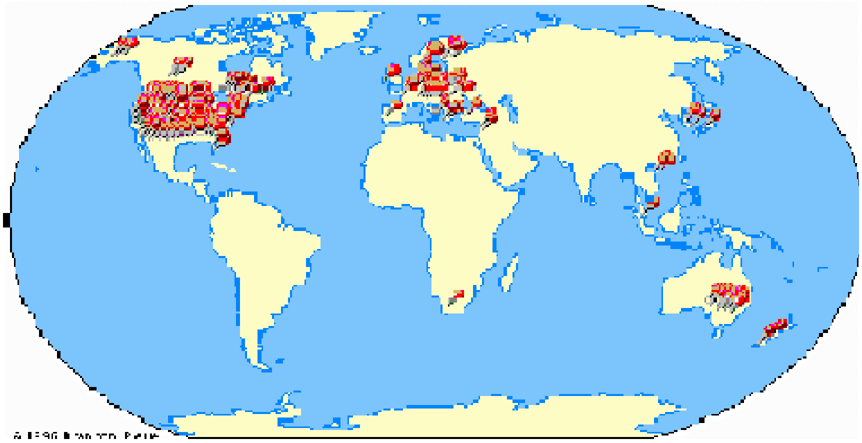


Figure 2. Geographical location of respondents.

3 Data collection: landscapes

3.1 Landscape component variables

Depending on the types of landscape chosen, there are many possible variables which may be used. Area and perimeter measurements of landscape components are often used, and may be combined with different distance zones (immediate, intermediate and distant). There are many references which may be consulted for information on uses of different variables: Linton 1968, Shafer et al. 1969, Morisawa 1971, Crofts 1975, Propst and Buhyoff 1980, Brush 1981, Patsfall et al. 1984, Kaplan et al. 1989, Bishop and Hulse 1994, Buhyoff et al. 1994, Hammitt et al. 1994, Orland et al. 1995, Wherrett 1997a, 1998.

Commonly used tangible variables include vegetation and non-vegetation (Shafer et al. 1969), flat, low hill, steep hill and mountain landform (Linton 1968, Brush 1981), obscuring vegetation (Hammitt et al. 1994) or visible land (Propst and Buhyoff 1980), sky (Propst and Buhyoff 1980, Hammitt et al. 1994) and water, which may be divided into different types, such as still, sea and moving (Wherrett 1997a). Colour variables may also be measured, in terms of red, green and blue bands (Propst and Buhyoff 1980). Intangible variables may include mystery, coherence and complexity (Kaplan et al. 1989, Orland et al. 1995, Wherrett 1998).

The variables chosen to be examined were:

- Landform Variables (see Figure 3): Area and Perimeter:
  - Flat landform
  - Low Hill landform
  - Steep Hill landform
  - Mountainous landform
  - Obscuring vegetation
- Sky and Water Variables (see Figure 3): Area and Perimeter:
  - Sky
  - Water
  - Moving Water
  - Still Water
  - Sea Water
- Colour Variables: Mean and Standard Deviation:
  - Red
  - Green
  - Blue
- Complexity Variable: Bytes per pixel in GIF image
- Coherence Variable: Number of polygons in each image over 1 % of the total area

3.2 Landscape photographs

Once the geographical region and variables have been set, the photographs can be collected. Depending on the rationale of the exercsie, these can be collecting during different seasons and weather conditions, or can be collected in identical weather conditions. It should be noted that it is almost impossible to collect photographs in identical conditions in countries such as Scotland, due to the unpredictability of the climate.

The photographs collected should display a wide range of the variables chosen. It is therefore necessary to collect more photographs than re-

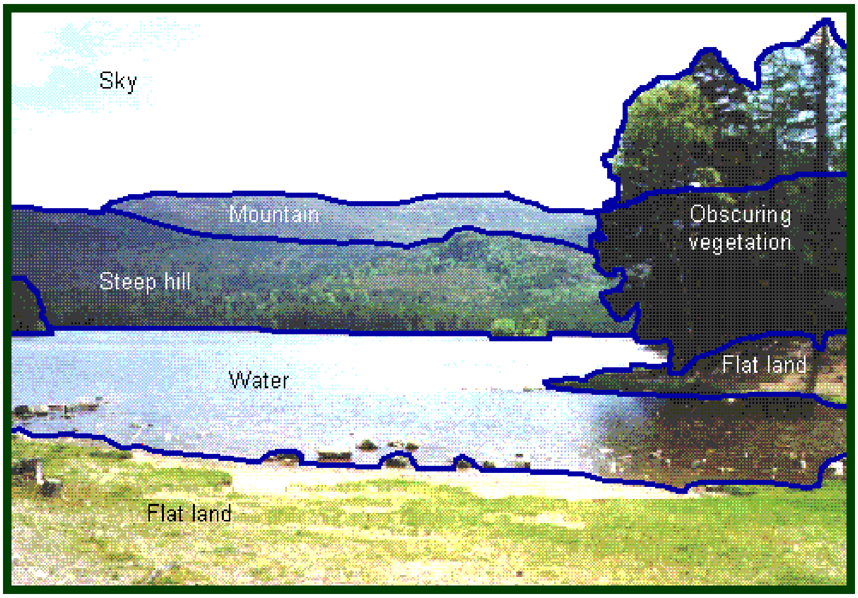


Figure 3. Example of digitised image with landform variables.

quired, in order to be able to choose the most suitable images for the survey. It may therefore be possible at this time to set aside a collection of images to be used to validate the model created in Step Seven. If a film camera is being used, care should be taken to use identical film throughout and have the photographs processed by the same company. If a digital camera is being used, the settings should be chosen before any photographs are taken and should not be changed afterwards.

The images require to be input to the computer, either through direct download or scanning. If scanning is required, images should be scanned at the highest possible resolution, depending on the availability of storage space; 200 dpi is considered the minimum resolution useable. Once the images have been stored, they must be manipulated by the graphics package. All images should be of an equal size ratio (length to width) and may therefore require some cropping to remove any accidental items (such as fingers). The images should then be saved in GIF87 format for transfer to HTML documents.

Photographs were taken over a number of years, in a variety of seasonal and weather conditions, using a Nikon 35mm Automatic camera and Kodak film and developed at the same branch of a major photographic company. Ninety of these images were then chosen for use in the survey.

The photographs were then scanned at 200 dpi and manipulated to be of the same length-width ratio.

3.3 Validation survey photographs

If no useable photographs remain from the initial photograph collection, a second, smaller set of photographs will need to be collected. These should ideally be from slightly different sites than the original photographs. The same process as used previously should be used for these photographs, to ensure all external variables are kept constant.

Once the quota of responses for the original survey has been completed, the validation survey images should be swapped for the previous images. The survey will continue to collect responses as before. Respondents should not be informed of the difference.

A second, completely new, set of photographs was collected from areas of Scotland not previously represented by photographs. 36 images were then placed in an Internet survey. The survey was not, however, sent out to the general Internet public as before, but used the Macaulay Land Use Research Institute Open Day in June 1997 to collect data. Members of the academic professions and of the general public were invited into the Institute and many were able to take part in the survey.

4 Data collection: preference scores

If the rationale chosen allows the survey to be undertaken electronically, an Internet survey can now be started. Otherwise, an alternative method of survey will have to be sought; possible suggestions include the work of Shafer et al. (1969) and Daniel and Meitner (1997) using images seen either in the field, on monitors or shown by slides. It should be noted that a traditional technique will be less environmentally friendly (i.e. require the use of paper and/or extra sets of photographs).

There are countless methods of constructing an Internet survey. One approach is to follow the work of Wherrett (1997a). The respondent is introduced to the survey and given basic instructions. They are then encouraged to practice scoring, to ensure they understand the levels of score which may be given. The technique then used is similar to the Scenic Beauty Estimation method (Hull 1986). All images are first seen by the respondent and then scored on the chosen scale; popular choices are 1 to 7 and 1 to 10.

Using HTML (hyper-text markup language) and a PERL (practical export and reporting language) script to return the data to the survey manager, this type of survey is simple to set-up and execute, requiring only a text editing package to write the documents. The URL (universal resource locator) of the introduction page can be submitted to search and broadcast engines, or can be sent by e-mail to a pre-determined sample.

An Internet survey was written, allowing each respondent to see 20 images. A randomising process was used to allocate respondents one of nine different sets of photographs. The URL was then sent to search engines and user groups, as well as to the Internet section of a major hardcopy newspaper. Screen snapshots of the introduction and scoring pages can be seen in Figures 4 and 5.

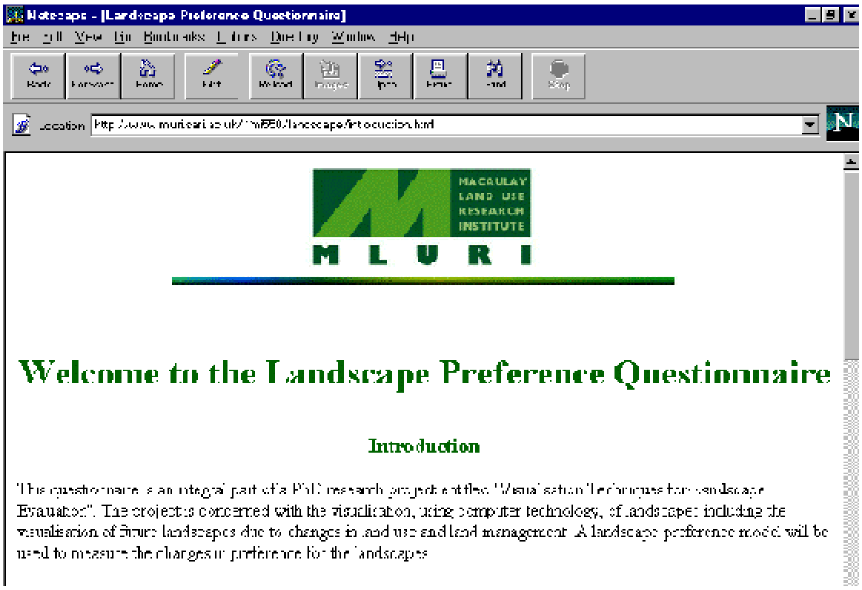


Figure 4. Example of introduction page.

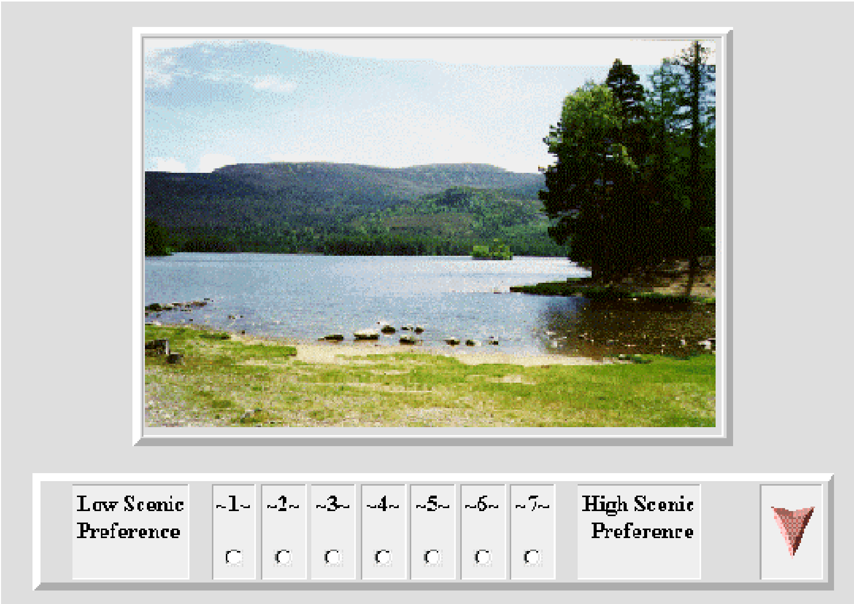


Figure 5. Example of scoring page.

5 Data analysis

5.1 Variable measurement

Whilst the survey is running on the Internet (or, if using a traditional technique, whilst associates are collecting preference data) the images may be digitised and the landscape components measured. The tangible variables being used can be measured using a GIS such as ERDAS Imagine (ERDAS 1994). All images should be re-sized to an identical size for comparability.

Areas and perimeters may be calculated using this method; results may then be transformed to any unit wished. Shafer et al. (1969) and Wherrett (1998) used units corresponding to an image of 40 by 32 and 40 by 27 units respectively. Colour means and standard deviations, if being used, may also be calculated using this software.

If intangible variables are being used, the method for measuring these will need to be defined. For example, a measure of complexity could be the size of the GIF image divided by the number of pixels in the image (Wherrett 1998). It is also possible to add other, non-natural, components. Structures such as pylons or farm buildings may be used (Tan 1997).

The variables were analysed using ERDAS Imagine. All were converted into TIFF format and thence into IMG format, at a size of 580 x 395 pixels. The chosen variables were then digitised or calculated, in the case of colour and bytes per pixel variables. Figure 6 shows an example landscape being digitised. The measurements of areas and perimeters in pixel units were then recorded and converted to WLCUs (Wherrett's Landscape Component Units), of which there are 1080 in any photograph. Figure 7 demonstrates an example landscape being converted to WLCUs.

5.2 Analysis of preference score results

There are a variety of methods for collating preference score data. Scores may be averaged, normalised or weighted. Once this has been done, any effects caused by socio-demographic types should be examined; for example, age and gender have been shown by some researchers to be important factors (Balling and Falk 1982, Lyons 1983, Hull and Stewart 1995).

The validation data will not require any socio-demographic analysis, although it should be compared to the original data for percentages of the various factors to ensure similar samples.

The scores from the first survey were analysed; two methods of normalising were employed – one by respondent and one by questionnaire (see the following equations). These two methods produced slightly different results and thus allowed the creation of models from both sets of results.

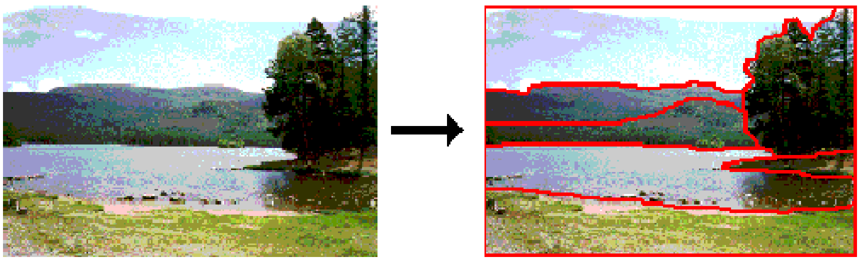


Figure 6. Animated GIF of photograph being digitised.

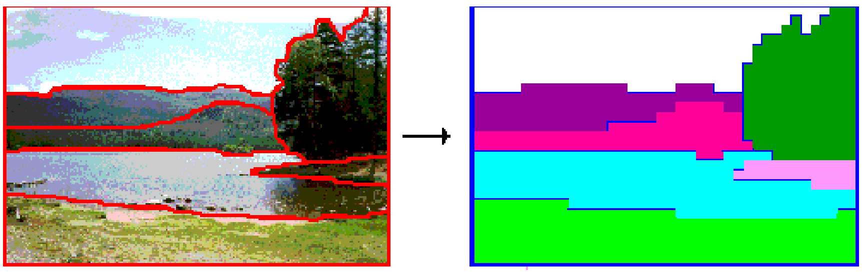


Figure 7. Animated GIF of digitised photograph being converted to WLCUs.

Normalising per questionnaire

$$\text{Score} = \sum_{\text{all questionnaires}} \frac{(\text{Photograph mean} - \text{Questionnaire mean})}{\sqrt{(\text{Count of respondents} * \text{Mean Square Error from ANOVA})}}$$

Normalising per respondent

$$\text{Score} = \sum_{\text{all respondents}} \frac{(\text{Photograph score} - \text{Respondent mean})}{\text{Respondent Standard Deviation}}$$

The socio-demographic information was analysed and none of the variables were found to be significant in determining score.

6 Model creation and validation

6.1 Multiple regression modelling

Once all landscape components have been measured and the preference data is complete, principal component factor analysis can be run on the landscape variable data to indicate which variables are most likely to be good preference predictors. As well as undertaking this for linear variables, it is wise to also use mathematical transformations and combinations of the variables, such as natural logarithms, squares and inverses; however, care must be taken to avoid any mathematical errors, such as divisions by zero.

Multiple linear regressions on the variables thus chosen will create multiple versions of models. Criteria for ideal models should therefore be set. The number of variables used should be kept low, while the regression fit should be kept as high as possible, resulting in no outliers in the residual plots. Using these and other criteria will allow the choice of a few models which may then be further examined.

Further examination includes analysis of how the model is working, which variables are acting as positive or negative predictors and if any combinations of variables are combining to become a quadratic factor.

The following example is one of the models created by this analysis.

Preference Y = Constant - A/bytes per pixel + B*red variance - C/(perimeter of mountain landform +1) - D/(area of water +1) + E*ln(area of steep landform +1)

where A,B,C,D and E are constants and $R^2 = 0.640$

The terms of the model can be explained in reference to their implications for landscape preference.

- The second term involves the negative inverse of bytes per pixel, which is a proxy for complexity; this term therefore states that as complexity increases, the preference becomes less negative so implying that complexity is a positive predictor for landscape preference.
- The third term states that red variance (i.e. the square of red standard deviation) is positive for landscape preference, i.e. that a wide spread of red colour in the image will improve the preference.
- The fourth term, alike the second, states that the perimeter of mountain landform is a positive landscape preference predictor, which is intuitively sensible.
- The fifth term, again involving a negative inverse of a variable, again implies a fairly obvious statement - that water is a positive landscape predictor, a result found by the majority of researchers.
- The final term, using the natural logarithm of steep landform, suggests that steep landform, as well as mountain landform, is a positive landscape preference predictor.

7.2 Model testing

The models which fit the pre-determined criteria the closest should now be tested on the preference data gathered from the validation survey. Correlations between the predicted scores and ranks and actual scores and ranks should be calculated. If correlation coefficients above 0.6 are achieved, the model is working well.

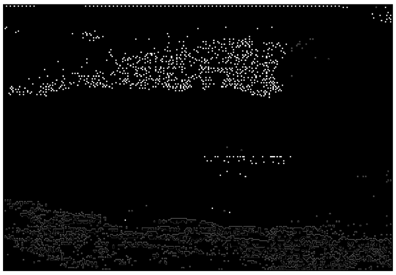
The model detailed in section 7.1 was compared to a second set of 36 photographs, as described in section 3.3. The correlations between these two sets were 0.604 and 0.605 for the scores and ranks of the 36 images respectively. These results validate the utility of the model.

8 Example of an application

One application of a predictive landscape preference model is to give indications of how preferences for a scene might change due to a change in land use management or policy. The model may be employed to show if the aesthetic value of a landscape is more probable to increase or decrease due to a change the landscape.

The following is an example using the model previously described. The landscape shown is the area around a popular beauty spot, Loch an Eilein, near the town of Aviemore in the Scottish Highlands. In this example there is a proposed land use change, which will involve the planting of a number of tree species around the loch, as shown in Figure 8.

Figure 8 shows the loch as it is now, and a photomontage of how Loch an Eilein might look if the proposed planting strategy went ahead. The loch is completely obscured, thus removing all water from the view. As water is a positive factor in



Loch an Eilein, Aviemore

Photomontaged image of Loch an Eilein

Figure 8. Loch an Eilein: before and after.

Table 1. Loch an Eilein landscape components variables.

Variable	Actual view (WLCUs)	Proposed view (WLCUs)
Bytes per pixel	540	650
Red Variance	5776	5625
Perimeter of Mountain Landform	48	52
Area of Water	214	0
Area of Steep Landform	129	33
Preference Scores	**0.4353**	**0.1171**

the predictive preference model, it is expected that this will decrease the scenic quality of this landscape.

The results from this analysis show that the preference of the general public for the proposed view is likely to be lower than that for the actual view. There would, therefore, be a presumption against the proposed change in land use, in terms of the aesthetic appeal of the landscape to the general public. As an alternative to this proposed change, another could be formulated which increased the preference score, thus increasing the scenic beauty of the area.

9 Conclusions

This paper has shown how a predictive preference model for natural scenic landscapes can be created in a straightforward and environmentally friendly manner. Such a model may be made in a number of days or over several months or even years, depending on the requirements set out in section 2.

A model created in this way could aid in aesthetic landscape planning. The methodology used to create the model is a highly flexible system, which can be easily extended to specific landscape or development types, allowing a variety of landscapes impacts to be examined. The use of a psychophysical model which uses tangible landscape attributes allows the predictive model to be objective and able to be automated to some degree. Predictive models, such as these, will never be able to exactly determine relative landscape preference, and they do not claim to do so. They can, however, give a highly useful guide to a general level of appreciation for, or discontent with, a natural landscape.

The use of the Internet as a medium to undertake the required survey work has several advantages: the availability of a geographically wide sample of respondents; the wide accessibility of the Internet; it requires far less paper and stamps than a traditional paper-based survey; and is a highly felxible method of data collection. Correspondingly, there are also disadvantages: the sample may have a non-ideal socio-demographic profile and will be limited to those who have access to the Internet. These and further issues are discussed by Wherrett (1997a, 1997b); the Internet has a place in visual preference research, but its limitations must be remembered.

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